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The Old Spanish Irrigation Works
of the Philippine Islands

Civil Engineer

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THE OLD SPANISH IRRIGATION WORKS OF THE PHILIPPINE ISLANDS

BY

STANLEY GARDNER CUTLER
B. S., UNIVERSITY OF ILLINOIS, 1908

THESIS

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U N I V E R S I T Y O F I L L I N O I S
T H E G R A D U A T E S C H O O L

May 3, 1911

I hereby recommend that the thesis prepared by STANLEY GARDNER CUTLER entitled The Old Spanish Irrigation Works of the Philippine Islands be approved as fulfilling this part of the requirements for the degree of Civil Engineer.

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P R E F A C E .

- - - - -

The writer having spent substantially three years in the Philippine Islands, as Assistant Engineer, Irrigation Division Bureau of Public Works, Manila, in charge of surveys and improvements on the Friar Land Estates, and having made a special study of irrigation in the Philippines, concluded to put on record his observations and study, which accounts for the present treatise.

- - - - -

PART I. INTRODUCTORY.

In any profession, aside from the description and discussion of modern methods, there stands a record of past trials, failures, and successes, which if not of so great practical importance is at least of distinct interest to members of that profession and perhaps also to the occasional well-read outsider as well.

Of course, it can not be claimed that the present engineering force in the Philippine Islands is making any great use of the methods in vogue before the occupation, yet in the consideration of local details, of which the members of this force are ignorant on arrival, most of the knowledge comes gradually, almost without acknowledgement, from continual contact with the results of those methods.

EARLY IRRIGATION IN THE PHILIPPINES.

1. ON FRIAR LANDS. The Friars, as they are called collectively, accomplished much, altho probably confronted by a simpler task than ours insomuch as the Filipenos were, in the early times, a more primitive people than at present, requiring more physical and less moral suasion. How much of the work performed by the Orders was actuated by selfish considerations, and how much by benevolence it is not the intention to discuss here. It is certain that as a rule the welfare of the Filipino improved as the coffers of the Friars filled. Large churches pleased the natives and attracted them, good roads made easier haulage, and irrigation made cropping more satisfactory to the farmer as well as to his clerical landlord. In most cases the former still refer to the old irriga-

tion as the most satisfactory.

Altho the Friars were not the only irrigators under the old regime, it can be assumed that their practice was the most extensive and the most economically managed. Their land was to a large extent close to the Manila market, and hence transportation was cheap. Their land was cultivated to a higher average extent than any other in the Islands, and had been so cultivated for a longer time. Again, it must be remembered that in those times the Friars were the cultured class, that men from every walk joined them, and that they were not even hypocritical as to their knowledge of engineering and cultivation. Their wealth was probably due more to sensible, practical business methods than to the alleged extortion. Such methods were not those of the Filipino, and were therefore hated.

So in taking up a description of the so-called Friars irrigation, it may be assumed that the latter embraced all the most approved points in contemporary design. The subject should be of interest, not only as a chapter in engineering history, but as an illustration of the methods used by our predecessors in handling such local problems as they met, as a time-tried recommendation for some particular procedures, and as a long-standing warning against others.

2. ON PRIVATE HOLDINGS. The irrigation of private holdings in the Philippine Islands is a development from the earliest efforts of the untutored savage, in some places undoubtedly aided by ideas from the Moros of the South, in others entirely original. In a country containing numerous streams subject to overflow, it is easy to see where ideas of diversion and of the benefits of irrigation originated.

It will be advantageous to consider some of the ideas cur-

rent at an earlier period than the Spanish, in order to find if possible how much the later builders copied to fit the country, and how much was a purely European development.

The following ideas, being utilized in old Igorotte and other hill irrigation, are undoubtedly primitive: (1) that the beds of most rivers fall at a greater slope than necessary to insure flow; (2) that the sooner the canal can be lead away from the immediate vicinity of the rivers the more permanent it will be; (3) that diversion into the subdrainage of the country is natural and insures an easy method of regaining the water lower down.

The first efforts at irrigation were fraught with frequent failure, in fact many old, unused canals can be found at the present time in which the grade is negligible or negative. The slope in level countries is much too flat, and that in sloping countries much too steep. The irrigation of the Igorottes, so much wondered at, occurs in a country where in any stream bed even an engineer will underestimate the longitudinal slope. We must not begrudge the Igorotte his dues for the skillfully terraced hillsides, but remember that his problem was after all a simple one.

Aside from the Igorotte irrigation, the writer has seen another and more original method used in the hill country of Eastern La Laguna, in which the entire bed of the stream is leveled, and made into steps, down which the water descends in a series of wide falls, and which are each completely cultivated.

As soon as we leave the vicinity of the wild tribes, we meet irrigation undoubtedly affected by European ideas. Most of the small irrigated holdings are irrigated by two general methods.

First, by low level canals, diversion being made by small boulder and brush dams replaced each year. These are constructed by piling the stones about the bottoms of bamboo stakes, against which are rolled bundles of cogon grass or earth bound in suale mats, the whole being given an upstream earth backing. They are built entirely without regard to impermeability. The second class of irrigation, surely a later one, is obtained by the diversion from an adobe-stone or lime-concrete dam, patterned after the Friar lands work on a small scale, into a medium level canal. The writer has seen diversions of the first class in Mountain Province, Pangasinan, Tarlac, Pampanga, Rizal, Bataan, Lloilo, and Zamboanga; and of the second in Bulacan, Bataan, and Laguna, exclusive of the Friars work.

In none of these cases has he seen a well developed distribution system, the canals seem all to be aligned according to trial and chance -- many being abandoned which would never run. These systems range in size from a fraction of a hectare to ten or twenty.

In taking up the question of adaptation, it is quite evident that all the existing structures in the Islands are of a design purely European -- indeed, from what the writer can learn, the old practice in Spain and the local practice are identical.

On the other hand the writer has mentioned that all the distribution systems herein mentioned differ from the usual practice in this particular -- that the main diversion was not the unit -- that it served only to make the supply permanent and sufficient in numerous small and more or less primitive units. This will appear in greater detail and very distinctly in the description of distri-

bution systems, and particularly those of the Malabon, Imus, and Sta Rose Estates. Perhaps however the best example of this is on the Orion Estate, in Bataan, where part of the flow of the main river is diverted into what would normally be a dry stream bed, and later raised from the latter in four separate places by primitive masonry dams. This feature of Friar irrigation was undoubtedly adapted from the previous native practice on account of the ease with which it could be employed particularly for such a crop as rice.

THE FRIAR LANDS -- LOCATION AND EARLY HISTORY.

The Friar Lands are scattered pretty widely throughout the Philippine Islands, occupying some of the choicest locations.* They include one large estate in Isabella province in the Cagayan River valley, Northern Luzon; a great number of small estates in Bulacan province, Central Luzon, most of which are situated along the present line of the Manila R. R.; a few small parcels in Rizal province surrounding Manila; one large tract in Bataan province; several in Cavite province, bordering on Manila Bay; several in Laguna province, along Laguna de Bay; a vast estate on Mindoro Island; and two on the East coast of Cebu Island.

The writer will endeavor to avoid mentioning too many of these estates, owing to the obvious confusion it would make for the reader, to his own slight knowledge of them, and to the fact, supported by the statement of the "Reports of the Philippine Commission", that outside of Cavite and Laguna the only estates having irrigation works worthy of valuation are Lolomboy, and Sta Maria Pandi, -- both in Bulacan. The writer has never visited the lat-

* See Plate I, page 7.





ter two, but believes that he has included four fifths of the irrigated area without them.

The early history of these lands is varied and interesting, but only the most casual outline can be given here. The foundation of such "haciendas" was invariably in large private grants by the various Governor Generals to Spaniards in reward for public or private services.

The estates of Naic, Sta Cruz, and San Francisco de Malabon were thus granted about the end of the sixteenth century, and descended thru various hands. The first named estate was obtained by the Jesuit Order in 1698 in bankruptcy proceedings. That order was at one time the largest landowner in the Islands, but was expelled by the Government which either confiscated or sold its lands at auction. Naic was again acquired by private individuals in 1795 and held by them till August 18, 1831, when it was bought by the Dominican Order for ₱25,000. Sta Cruz was held privately until February 18, 1727, when it was obtained by the Augustinians in satisfaction of claims against the owner. It was returned to the heirs of the latter on February 6, 1754, who in turn sold it on March 2, 1761, to the Sto Tomas College. This institution was under the guardianship of the Dominican Order, which rather in violation of the trust transferred the strip between the Timalan and the Naic Rivers to the Naic estate in its own name. The San Francisco Estate passed thru many hands, was much divided, and was finally acquired by parcel purchases in 1877, by the Augustinian Order.

The Imus Estate originally consisted in two principal ones, the San Juan and the San Nicolas haciendas. They originated in Spanish grants from 1590 to 1595, and in several small purchases

from natives (1626-1631). The former estate was purchased by the Recoleta Order in 1635 for ₱12,500; the latter was willed to them on November 4, 1666, in return for various religious services; while one other considerable tract of the present estate was bought by them in 1690.

Biñan and Sta Rosa were originally one estate, formed by grants in 1591, 1593, and 1635. By June 26, 1653 all the land had been acquired in small purchases by Sto Tomas College, which augmented it by various purchases from natives from 1624 to 1641. In 1744 after many years of litigation a famous decision was made by the Philippine court acknowledging the claim of the College to a great deal of land in the Municipality of Silang, Cavite. It is not known exactly when these estates began to be regarded as separate units -- probably upon the establishment of a municipal government in Sta Rosa.

The Calamba Estate originated in grants from 1678 to 1698. In 1759 it was conveyed to the Jesuit Order for ₱41,537, and upon the expulsion of that order from the Islands was leased to the Government for several years. In 1792 it was sold at auction, bringing ₱40,007, and on December 4, 1832 it was deeded to the Dominican Order upon payment of incumbrances amounting to ₱51,263. Legal disputes over the land in this estate were especially frequent and bitter.

Thus we find in the latter quarter of the nineteenth century, that all of the land under consideration was in the control of the three religious orders, as indeed were all the lands subsequently bought by the Government. The Dominicans owned or con-

trolled Calamba, Sta Rosa, Biñan, Sta Cruz and Naic; the Recoletos Imus; and the Augustinians, San Francisco de Malabon.

Before the actual outbreak of the insurrection, the hatred of the Friars became active enough to drive most of them to Manila; and it was evidently the fear of losing their hold completely that impelled them to make general transfers to various private corporations organized for the purpose. It has never been definitely ascertained what share the Orders continued to hold in the profits and management, but it must have been considerable. The first such transaction was on February 7, 1893, by the Augustinians to a company known as the "Sociedad Agricola de Ultramar", organized in Spain. The second was by the Recoletos, on February 15, 1894, to the "Fomento de la Agricultura de Filipenas", which on March 17, 1900, re-transferred the Imus Estate to the British Manila Company of Hongkong. The Dominicans, on August 8, 1898, transferred their land and that of Sto Tomas College to R. H. Andrews, who founded an English corporation, the Philippine Sugar Estates Development Company, on January 29, 1900. All these transfers, in the light of future happenings, can be regarded only as development or disposal contracts.

THE FRIAR LANDS PURCHASE OF 1904. Upon the establishment of a civil government by the Americans, means were at once sought of removing permanently the curse of church ownership of lands, and while the development companies outwardly resented bitterly the imputation that they were not freeholders, in the end it became necessary for them to enter into negotiations with Mr. Taft and the apostolic delegate.

Numerous difficulties presented themselves, a question of

especial importance being the evaluation of the estates, which was entrusted to a Filipino surveyor, Sr. Villegas. This task, as well as his survey, was but imperfectly done -- the areas especially being greatly in error and requiring a later survey by American employees and a consequent adjustment of price in 1904-5. Deeds were often missing, and boundaries were indefinite in spite of the most minute inquiries concerning them, and a very trying complication arose over the peculiar guardianship of the Sto Tomas interests by the Dominicans. For some time it appeared that the large estates of Biñan, Sta Rosa, and Sta Cruz might be withdrawn from sale, as legally they still belonged to the College. Encumbrances had to be cleared from several of the estates.

Financially there was not much difficulty. ₱14,000,000 worth of bonds were issued by the government, payable in 30 years and redeemable in 10 years at 4 per cent, which sold readily in the United States. It was planned to turn the administration over to the Bureau of Lands, and to lease the lands immediately upon purchase to former tenants at such a rental as would pay the interest on the bonds plus the cost of administration, and to apportion the cost of the various classes of land so that on sale the sum would equal the amount paid for the estate plus the cost of permanent improvements.

Sales agreements were made and the transfers accomplished slowly-- on October 5, 1904, the Recoleta Order was paid ₱597,564.14 for the Mindoro estate; on October 24, 1904, the Sociedad Agricola received ₱4,154,665.12 for the lands of the Augustinians; on February 7, 1905, the British Manila Company received ₱2,073,311.46 for the Imus Estate; and on October 20, 1905, the titles at last set-

tled, the Philippine Estates Company were paid ₱7,043,314.00 for the lands of the Dominicans and of Sto Tomas College, making a total of ₱13,868,854.72 for an area of about 158,676 hectares.

Various questions of the detailed cost of the land under consideration will be discussed later, and some additional data are presented in tables. The leasing of the land proceeded directly after the accomplishment of the purchase, and proceeded slowly but regularly. The estates have mostly been sold by this date, the Calamba land having been disposed of but a few weeks ago. Altho the land is paid for in installments, the cost of administration has been large, and the land is rather dear in consequence.

The first Superintendent of Irrigation was appointed by the Bureau of Lands in September 1905, and work was started on the rehabilitation of the irrigation systems. This will be discussed later.

CROPS RAISED IN SPANISH TIMES. The first attempt at cultivation on the present Friar Lands was the raising of sugar cane, which previously covered the greater part of the land. The raising of rice, which later spread to probably one fourth of the church land in Cavite and Laguna, was a later development, probably only extending to the limits of irrigation at any given time. Hemp, tobacco, and a little native garden truck were very limited, and need not be considered.

No data are available as to the exact amount of rice raised on the estates in Spanish times -- but, as it was not until after the war years of 1898-9 that the Islands began large importations of rice, we may safely state that greater total crops were raised then than now. It is not probable that the unit crops have

changed much, since the method of cultivation has remained unchanged.

METHODS OF ADMINISTRATION. Previous to the delegation of the development to corporations, the estates were managed a good deal as large private haciendas are managed in the Islands at present. The convent of the order was established in the principal town of the estate, where the Friars also built their storehouses. Besides the clerical members of the order, who did much of the purely administrative work, there were numerous lay brethren who attended to the more menial duties, -- surveying, constructing, collecting rents, and settling disputes among the tenants.

The lease was commonly in the form of an agreement, the tenant receiving necessary animals and implements, and binding himself in return to deliver a certain proportion of his crop to the landlord -- this being anywhere from 1/10 to 1/2. Sometimes this crop rent applied only to one growth annually, the tenant keeping the whole of any other crop raised.

Labor was arranged for in various ways -- sometimes by direct payment, but oftener in substitution for rent or religious services, while every man was supposed to work several days annually on the roads. Deliveries of crop rent were generally made at the central hacienda store-house, but sometimes at various local centers.

It is possible that the rents gathered thus were collected fairly, and not accompanied by the extortion so prevalent in government taxation in those days; but we are reasonably certain that the methods used were strictly business-like, and that the orders maintained a very close hold on the liberties and resources of the tenants.

CROPS OF THE FRIAR LANDS.

AGRICULTURAL PRODUCTS. The Friar Lands in Spanish times were very highly cultivated, the remains of old rice and sugar mills and of old cultivated fields being still visible far beyond the present limit of agricultural utilization. However the decrease in area cultivated is not so evident in rice land, insomuch as that land, lying lower and closer to the coast, is nearer to the centers of population, and has not therefore been abandoned. Also land once irrigated has proven too valuable an investment to neglect entirely.

In general, in Spanish times as now, the rice area outside of the irrigated lands was small, being confined to small patches of dry or mountain rice raised for consumption in the vicinity. This rice is of a poor grade, the value of the small amount raised being negligible. Within the area irrigated, rice was almost the only crop -- at least during the part of the year for which the supply was sufficient, -- although it was sometimes alternated with sugar or comotes.

Above the irrigated area, and often in small tracts within it where irrigation was difficult, the principal crop was sugar cane. This as far as the writer knows was never properly irrigated in the Philippine Islands, altho artificial watering is known to add much to the quality and certainty of the crop. Sugar was formerly a much more valuable crop than rice, but the scarcity of the latter at present evens matters somewhat; besides such a large capital is not required for the handling of the latter crop. At present the sugar area in the Cavite and Laguna Friar Lands is com-

paratively small, especially in the former; but in Spanish times the two were probably nearly equal.

Other crops raised in small patches, or as alternates to the rice and sugar were maize, comotes, frijoles, and various other native garden truck. Hemp was cultivated to a small extent in the upper country. There is little doubt that from the earliest times the value of the rice crop on these lands was greater than all the others combined; and the same statement is especially true at present.

THE CULTIVATION OF RICE. At this point a few words are necessary relative to the method in use in irrigating a rice crop in the Philippine Islands. Except for the so-called mountain variety, an unimportant product, all properly cultivated rice requires a more carefully controllable water supply than is afforded by the rain alone.

The meteorological conditions prevalent in this section of the Philippine Islands will be discussed at length in another paragraph; for the present it need only be remembered that in these provinces about 75 per cent of the total rainfall occurs in the months between June and October, the remainder being much too occasional and uncertain to afford any surety. The influence of various local conditions on the availability of irrigation water will also be discussed later -- in the paragraphs immediately following a sufficient supply will be assumed.

The first step in the development of rice irrigation was undoubtedly the damming up of various small creeks, down which the heavier rains sent a sufficient supply of water for one crop; and the regulation of the field supply by raising or tearing down the

dams, and by placing checks in the field ditches. From this it was only a step to the securing of more dependable supplies, either by the diversion from larger streams or by the consolidation of small ones; and this step, securing the extra crop each year, was the work of the Friars.

A necessarily brief description of the program of operations for a rice crop under dependable irrigation, and as practiced in the Philippines follows:

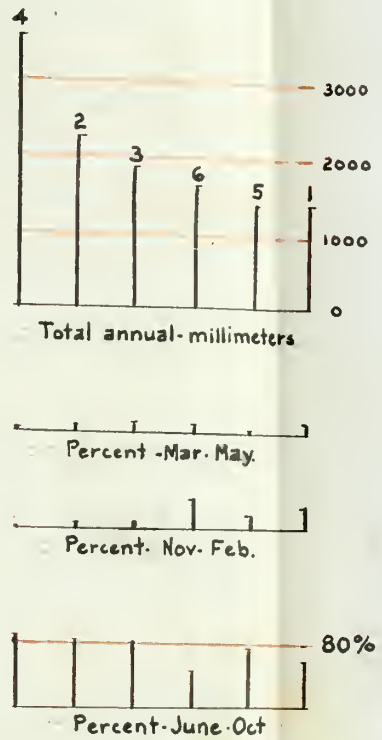
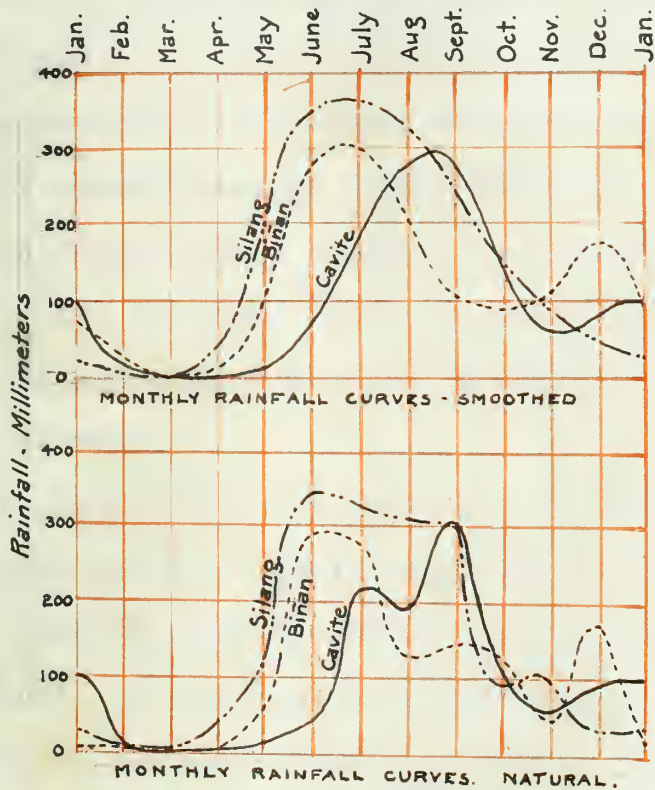
The farmer divides his field into two portions -- one consisting of a small fraction, perhaps a hectare to every ten, generally located close to means of communication and irrigation, or in a few instances chosen on account of the better quality of the soil -- which will be called the "seed paddy" -- and the remainder of his cultivated lands, properly dyked off, which will be called the "crop paddy".

About the time of one harvesting in the crop paddy, water will be turned into the seed paddy, and the latter will be plowed and puddled until it becomes soft, yielding, and smooth to a depth of about 0.3 meter. The seeds are then sown by thrusting them, by hand, a short distance into the soft mud, and some 0.2 meter apart. The water is again lowered to just barely cover the soil. In a day or two the rice sprouts appear and grow rapidly, the water being raised just beneath their heads, until they gain a height of about 0.1 meter, at which height the level is held. In the course of about one month after planting, the sprouts reach a height of 0.2 meter, at which time the water is drawn off, and the surface soil allowed to harden slightly. The farmer then enters and pulls the sprouts making them into small bundles.

In the meantime the former crop in the crop paddies has been harvested, and the ground plowed under some 0.2 meter of water, which is allowed to remain at that level. The bundles of sprouts are brought to the crop paddy, and each blade is planted singly, about 0.2 meter deep, with an interval of 0.3 meter between sprouts. The sprouts soon take root and grow, the irrigation water being raised with them until it is about 0.3 meter deep. When the plants are about 0.8 meter high, the water is drawn off, and the heads turn from yellow green to straw color, at which time the rice is mature. The harvesting is then done by means of small, hook-like knives, and the regular process of winnowing and cleaning commences. In the meantime another seed paddy has been planted, and the process is repeated.

This procedure is generally limited to two crops a year, on account of the natural antipathy of the native to employing himself to excess and the large supply of water necessary in the dry season, but in Calamba and several parts of Cavite three crops have been raised with success. Plate II, page 18, will illustrate the sequence, as well as serving as a base for the calculation of duty in the following article.

DUTY OF WATER. Altho the amount of water actually employed in maturing a rice crop has been estimated at various places in the Friar Lands, little dependence can be given to such estimates owing to the complicated systems of paddy rotation (called "tatils" in India) and the neglect to take account of run off. For the present the Irrigation Division, Bureau of Public Works, employs a duty factor of one litre per second per hectare, which

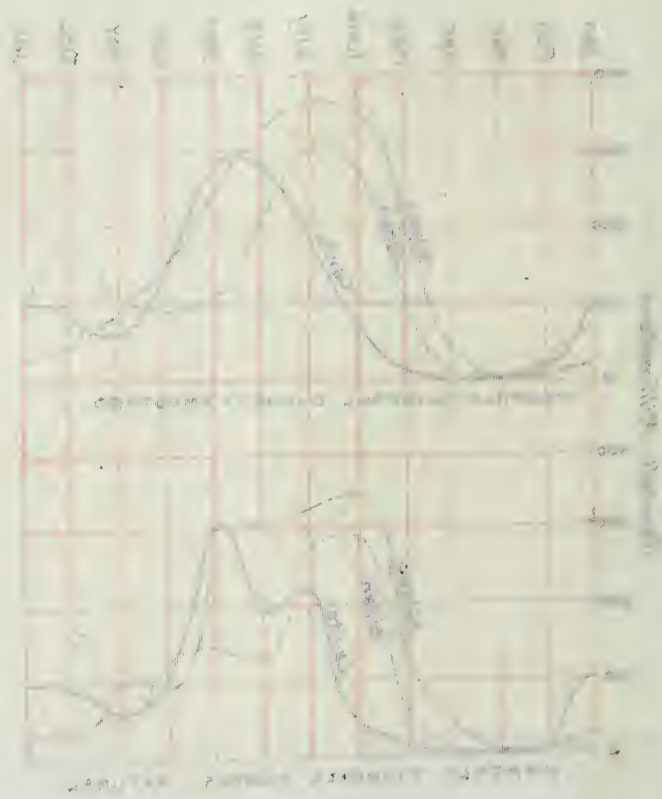


| SEASON | RAINFALL DATA FOR VARIOUS DISTRICTS OF LUZON. | | | | | |
|--------------------------|---|---|---|-----------------------|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | Cagayan Valley Tuguegarao Bayombong | N.W. Coast Vigan S ^a Fernando Dagupin | Central Valley Tarlac San Isidro Arayat Merilao | Zambales coast Iba | Vicinity of Manila Cavite Silang Binan | S.E. Coast Tayabas N ^a Caceres |
| Total Annual Millimeters | 1379 | 2280 | 1870 | 3617 | 1407 | 1634 |
| Percent June to Oct. | 58.8 | 86.9 | 80.2 | 92.9 | 76.6 | 48.4 |
| Percent Nov. to Feb. | 25.2 | 3.8 | 7.4 | 2.7 | 17.6 | 38.4 |
| Percent Mar. to May | 16.0 | 9.3 | 12.4 | 4.4 | 5.8 | 13.2 |

Same data shown graphically above, to right.

RAINFALL CURVES AND TABLE
CAVITE AND LAOYAN

By authority of the
S. G. CUTLER



| RAILROADS OF THE UNITED STATES | | | | | | MILES |
|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 | 2 | 3 | 4 | 5 | 6 | |
| Grand Total | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 |
| Atlantic Coast | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 |
| Great Lakes | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 |
| Mississippi Valley | 300,000 | 300,000 | 300,000 | 300,000 | 300,000 | 300,000 |
| Pacific Coast | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 |
| Rocky Mountain | 500,000 | 500,000 | 500,000 | 500,000 | 500,000 | 500,000 |
| South Atlantic | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 |
| South Central | 700,000 | 700,000 | 700,000 | 700,000 | 700,000 | 700,000 |
| South Western | 800,000 | 800,000 | 800,000 | 800,000 | 800,000 | 800,000 |
| North Western | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 |
| North Central | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 | 1,000,000 |

factor is usually designated 1 sec.-lr. per hectare. This is an average figure, and the following discussion will show that with this figure, a very systematic method of paddy rotation must be employed. On land supplied with this amount, under the present uneconomic use, it is necessary to let some of the paddies lie fallow on alternate dry seasons; and on land on which two crops are raised on all portions, a larger continuous supply must be available. Most of the apparent discrepancy between a continuous supply and an equal supply apportioned as is hereafter outlined, is obviated by the fact that the various stages of cultivation of the paddies in any locality are not simultaneous, planting and all subsequent operation being later in some than in others -- thus striking a sort of natural average.

The figure for the duty for the water stated above is well in accord with others. The Friars, in such reports as are available, used somewhat over one sec.lr. per hectare; the Dutch in Java use 1.2 sec.lr. at the head of field ditches; about 1.1 sec.lr. is used on rice in the Sefi season in Egypt; about the same in Madras, India; from 2.0 to 2.7 sec.lr. on rice in Spain; 2.0 sec.lr. on rice on the Cavour system in Italy; while a nominal duty of 1.0 sec. lr. is commonly used in France and Spain.

As far as the writer can determine, no actual experiments have been made in the Philippine Islands to ascertain the value of absorption and evaporation, and since the results are questionable at best, he can only use those obtained in other tropical countries in estimating a figure for duty on rice.

Mr. R. G. Kennedy, in "Punjab Irrigation Branch papers",

sites the opinion that in a field which is approximately of the same size as the average paddy it would take at a discharge of 16 sec.lrs. ($\frac{1}{2}$ cu.sec.) 1.36 times the quantity of water to cover the field at first flooding, as at a discharge of 32 sec.lr. This is of course evident in principle; and the native takes account of this fact by flooding his fields in succession, closing off the lower ones until the upper are filled, or by waiting for a heavy rain before plowing. The same investigator has made experiments to obtain the absorption factor in soils at various successive periods.

Using Mr. Kennedy's figures for the Punjab we have the following amounts of water to be supplied to a rice crop per hectare of crop paddy:

(1) To cover a seed paddy of 0.1 hec. with a supply of 32 sec.lr. will require a depth of 8.1 cm. This depth will necessitate a total supply of 81000 lr., running for 0.029 day.

(2) The water has then to be raised to a depth of 0.2 meter which will require a quantity of 200,000 lr. or a supply of 0.12 sec.lr., flowing for 20 days. To this must be added an amount representing the evaporation and absorption, probably not more than 0.015 m. per day, as all this land has a very stiff artificial hard pan, made by frequent puddling and shallow plowing. This added amount, 15,000 lr. per day, will necessitate an added supply of 0.18 sec.lr.

(3) The crop paddy has then to be flooded with a supply of 32 sec.lr., requiring in all 810,000 lr. entering in 0.29 day.

(4) The water has to be raised to a depth of 0.2m. in 30 days which will necessitate a supply of 0.77 lr. to which must be

added 1.80 sec.lr. for evaporation and absorption.

(5) The water must be raised 0.05m. more in the next 30 days with a supply of 0.19 sec.lr. The absorption will probably drop somewhat by this time, owing to the settlement of silt. A supply of 1.50 sec.lr. will be allowed for the latter.

(6) The water must then be raised 0.05m. more in about 15 days with a supply of 0.38 sec.lr. + 1.20 sec.lr. for absorption.

Then at a rate of 0.01m. per day, it will require 30 days to drain the paddy.

We have therefore the following resume, showing the supplies required and their durations for an average crop of rice unaided except by irrigation water.

| | TIME days | SUPPLY sec.lr. | QUANTITY lr. |
|---------------|--------------|-------------------|------------------|
| 1. SEED PADDY | 00.029 | 32.00 | 81,000 |
| 2. " " | 20.000 | 00.30 | 500,000 |
| 3. CROP PADDY | 00.29 | 32.00 | 810,000 |
| 4. " " | 30.00 | 2.57 | 6,661,000 |
| 5. " " | 30.00 | 1.69 | 4,380,000 |
| 6. " " | 15.00 | 1.58 | <u>2,048,000</u> |
| Total | | | 14,480,000 |

For three crops a year this quantity must be reduced to a base of 120 days, giving an average required supply of 1.4 sec.lr. For two crops the base can be extended to 180 days, with a supply of less than 1.0 sec.lr. Most of the foreign duties are computed to a base of 185 days for one crop, and the foregoing results, as

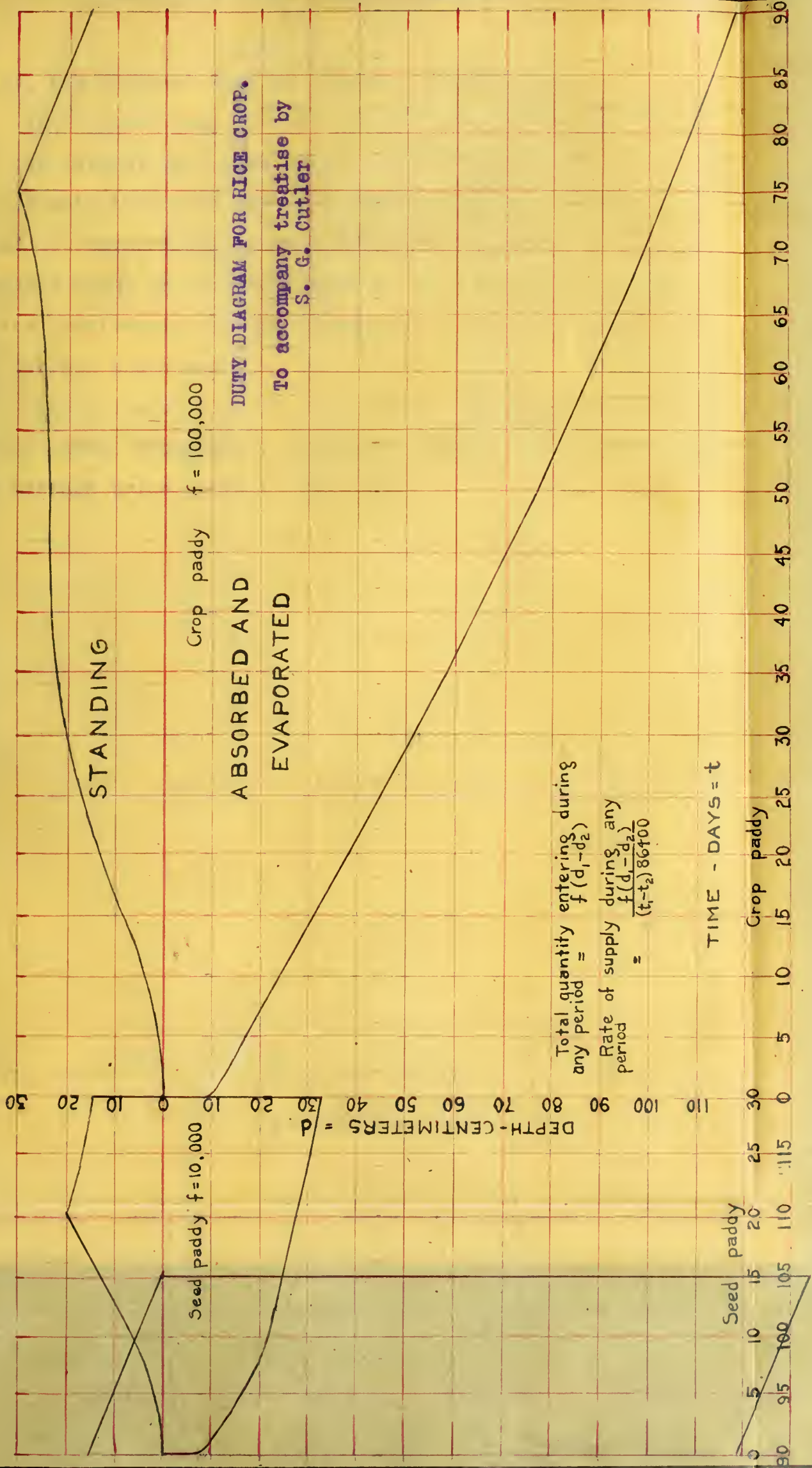
well as the writers personal observations, show that three crops can be obtained only under the most favorable conditions.

Altho the above figures were obtained independently and agree rather closely with empirical ones in use in the Philippines and elsewhere, the writer lays no claim to having deduced a dependable duty, his intention having been merely to give an idea of the relative amount used at various stages. It will be noted that no allowances have been made above for ditch losses. Plate III, page 23, shows the above results graphically. Actually the irrigation supply is always augmented by the conservation of what rain water falls on the paddies during cultivation.

COMPARISON OF IRRIGATED AND NON-IRRIGATED CROPS. The crop capability of a hectare of rice land varies from 20 to 70 cavanese. Closer than this it is unnecessary to go, owing to the great variation in methods and results on neighboring tracts of land.

The presence during one season of the year of dependable irrigation which can be regulated to the best advantage, is generally considered to increase the yield about 25 per cent, while irrigation during the entire year, by insuring the extra crop although not quite so plentiful as the first, may be said to increase the yield 100 per cent over an unirrigated area. The raising of a third crop is very unusual, and can not be said to be practiced on any considerable area. Probably not more than 120 per cent increase is ever gained by irrigation.

There is no object to be gained in copying data on this subject from current reports, which are widely varied and incomprehensible. For average values it can be assumed that two cavanese of seed will sow one hectare of land; and if this raises the above



DUTY DIAGRAM FOR RICE CROP.
To accompany treatise by
S. G. Cutler

TO SECRETARY TREASURY OF
U. S. DEPT. OF THE INTERIOR

FROM DIRECTOR FOR HIGH CROPS

WASHINGTON

DECEMBER 1900

DEAR SIR:

REPLY

quantity, the increase will be from ten to forty fold.

The highest crop ever mentioned to the writer was 80 cavanese; the largest ever seen by him was about 60 cavanese, and he would estimate that with two good seasons a year a maximum yield would be 100 cavanese, while with available water for three crops 120 cavanese might be raised. However, to these increases must be added the inestimable factors of dependability, and ease of cultivation for man and animal.

The price of rice in this locality varies from ₱1.50 to ₱5.00 per cavan, according to locality, season, demand, and supply. A fair average price is ₱2.50 per cavan.

LOCATION OF LANDS CONSIDERED.

COMMERCIAL. Little need be said regarding the commercial advantages of the Friar Lands location. The advantage of the location is evident, even to a foreigner, from their proximity to Manila -- see the map, page 26 -- in the earliest times, before the introduction of steamboats, they were accessible by means of bancas and lorchas, native craft which could either be poled or sailed across the Bay, or thru its bordering marsh channels from Cavite, or down the Pasig from La Laguna. The estates of the former province while not bordering directly on the Bay, are at least supplied with tidal rivers sufficiently large to afford passage to their lower ends. Those in Laguna province all border directly on Laguna de Bay.

The early introduction of coasting and river steamers must have been of great advantage to the Friars, reducing the time of passage from twenty or thirty to one or two hours, but the durable nature of all their products and the relative charges left most of their patronage in the original hands -- in many cases they owned their own bancas. The Laguna steamboat line, in Spanish times the only rapid means of reaching that province, made stops at Muntinlupa, Biñan, Sta Rosa, and Calamba, while the other lines on the Bay touched at Imus, Sta Cruz, and Naic. The town of Cavite in those days was a shipping center for all the surrounding country, even the largest vessels stopping there on their way in and out of the Bay. The Manila R. R., branches of which now tap both Cavite and Laguna, was not extended to those provinces until after American occupation; but the Northern branch, extending to Dagupin in Pangasinan, had

been completed since 1893, and goods could be transhipped to points in that direction very easily by means of spur tracks in Manila reaching the wharves of the Pasig River.

Within the estates all transportation was by road. The country was well supplied with trails, most of them in a much better condition than at present; but good roads were few. However in most cases the tenants were supposed to deliver the produce at a central hacienda house; and if not the Friars were of course well supplied with bulls and carabao. The hauls were in many cases lengthy, for instance in the Imus Estate, where the head of irrigation is about 13 km. from the hacienda headquarters. The probabilities are that the Friars were able to make this haul with a 500 kg. load for less than a peso, at any rate for a very small proportion of the value of the rice. The difficulty of cultivation and the scarcity of cattle since the invasion of the rhinderpest, has made these hauls much more expensive -- of course neglecting the general raising of prices since American occupation; and it is probably for that reason that much of the upper land, previously cultivated and irrigated, is now waste and the trails are in such poor condition.

The distances from Manila by water to the various estates in the most direct line is as follows: Naic 38 km., Sta Cruz 25 km., Imus 20 km., Biñan 37 km., Sta Rosa 42 km., Calamba 55 km. The probable maximum haul for rice to the point of shipment was: in Naic 9 km., Sta Cruz 5 km., San Francisco (to Sta Cruz or Imus) and Imus 13 km., Biñan and Sta Rosa 8 km., Calamba 5 km. In fair weather Imus and Sta Cruz might be reached by banca in one day, but all the other points would require two or more. At the present time, al-

most all the produce of the estates is shipped to Manila by banca or lorchas, but the latter are most commonly towed. Shipping rates by rail are high, and not much faster or more satisfactory than by water.

GEOLOGICAL AND GEOGRAPHICAL. To understand the topographic situation of the lands under consideration, it is necessary to get a general idea of the whole geographic structure of central Luzon - see Plate III, page 23. This island is formed by part of a submarine range, which stretches from Japan on the north to Australia on the south. The general opinion of scientists is that in quite recent geological times the present island was divided by a strait stretching from what is now the Gulf of Lingayen to Manila Bay, the eastern island consisting of the Cordillera with the high lands of Ilocos, Isabella, Cagayan, and Neuva Viscaya at the north, and some outlying peninsulas at the south; and the western island of the Zambal and Bataan ranges. The sea between the ancient islands has been filled in by silt carried from the mountains by the Agno River system at the north, and the Pampanga system at the south. The Central Valley, as the stretch of low land between the mountains is usually called, is uniformly flat, and one can pass thru its entire length without rising over fifty or sixty meters. The divide between the two rivers is slight, so nearly imperceptible in places that grave derangements have been caused by small canals diverting from one system and draining into the other.

The Pampanga system, which alone has any connection with our topic, heads in the mountains of Pampanga, Bulacan, Neuva Ecija and Neuva Viscaya, its tributaries uniting in the first two provinces to form the deltaic streams, Angat, Pampanga, and Guagua.

Tide water in these streams reaches some twenty miles from the Bay, and the alluvial plain between them, where not salt, is very fertile. Somewhat apart from this system tho essentially related to it, is the Maraquina-Pasig River. This reaches Manila Bay from the east, thru a deltaic mouth, which if the process of sedimentation continues will eventually be extended to meet the deltas of the Pampanga system, and will be merged in them as they have been merged in each other in the past.

Another result of the sedimentation has been the formation of Laguna de Bay. The tract now occupied by this lake was probably closed off from the sea by the silting up of the Maraquina River delta, and also by the peculiar condition continued at present -- that the former river in flood runs into both Manila Bay and Laguna de Bay, rising higher than the water level of the latter. Thus the low country between and above the junction of the Maraquina and the Pasig, and also the outlet of the latter are continually being raised, as also is the bed of Laguna de Bay. Besides this stream, several other extensive drainage areas have supplied material to the alluvial land surrounding Laguna de Bay, noticeable the Mabitoc, Pagsanjan, Sta Cruz (Laguna Prov.) and San Juan Rivers. The characteristic of all these alluvial plains is the low gradient and marshy beds of the streams near their mouths. The last named made land, is of course of small extent, as is that at the mouths of the small Cavite rivers, and also that along the Manila Bay side of Bataan.

The topographical map, Plate III, page 23, should be consulted in following out the above discussion, otherwise its connection with the subject can not be appreciated.

The alluvial land above described is enclosed on all sides -- with the exception of the small Corregidor channels -- by mountain ranges rising precipitate in places but generally having a border of rolling foot hills. To the east the Pampanga, Angat, Maraquina and some of the streams of the Laguna basin, rise in the Cordillera to the south; the drainage of Cavite and of the greater part of Laguna is from a spur of the Cordillera which runs westward from Tayabas to the entrance of Manila Bay, this same range completing the walls north of the strait in the Bataan and Zambal ranges.

It will, of course, be evident that the irrigation of the alluvial plains can most advantageously be effected by diversion in the foot hills, where the rivers while presenting a rapid drop are not so precipitate or canyon bound as in the mountains. Low line irrigation can be effected only in very large or very small units. The great rivers of the north, flowing slowly thru soft materials and subject to overflow, are out of the question for moderate sized units, where controlling works would be of prohibitive cost and the irrigation supply must be raised above flood level.

In Spanish times many factors prevented the formation of large units: (1) the uncivilized condition of the inhabitants at distances from the coast, (2) the absence of laws and customs respecting communal irrigation, (3) the unfamiliar engineering features of such systems, and (4) the fact that none but the large hacienda owners desired irrigation on a considerable scale.

In descending to medium sized units, we find that all the estates under consideration are favorably situated -- that is, present a sufficient alluvial area for cultivation, are bounded at

a short distance by a range of rolling foot hills advantageous for diversion, above which rise the mountains, forming a large and in most cases (due to the presence of springs) a perennial runoff. It is this difference in topography which causes the occurrence of much more highly developed works in Cavite and Laguna than in Bulacan, since the latter at least in the vicinity of the Friar Lands is wholly flat and alluvial.

Turning to the more minute topography in the vicinity of the former estates, it will be seen from the map, Plate I, page 7, that they lie in a sort of pocket at the southern end of the Central valley. At the south the land is almost entirely shut off by the range which stretches from the Corregidor channel to Laguna de Bay and which averages some 800 meters high. In Cavite the slope rises gradually from the alluvial plains to the general crest of the above mentioned range, isolated peaks alone being visible above the general slope. This formation also continues to the east of Taal Lake, in the valley of the San Juan River. This sloping plateau of Cavite breaks off quite suddenly to the east, where the descent to Laguna de Bay starts. A good idea of the situation can be gained by an observer from the shore of Laguna de Bay, from whence the Cavite plateau can be seen rising in low, rolling hills to the west; above these hills the surface is flat and rises gently towards the south, where it breaks at the foot of isolated peaks. Between this plateau and Mt. Maquiling (on the south) appears a gap, caused by the more gradually ascending valley of the San Juan River.

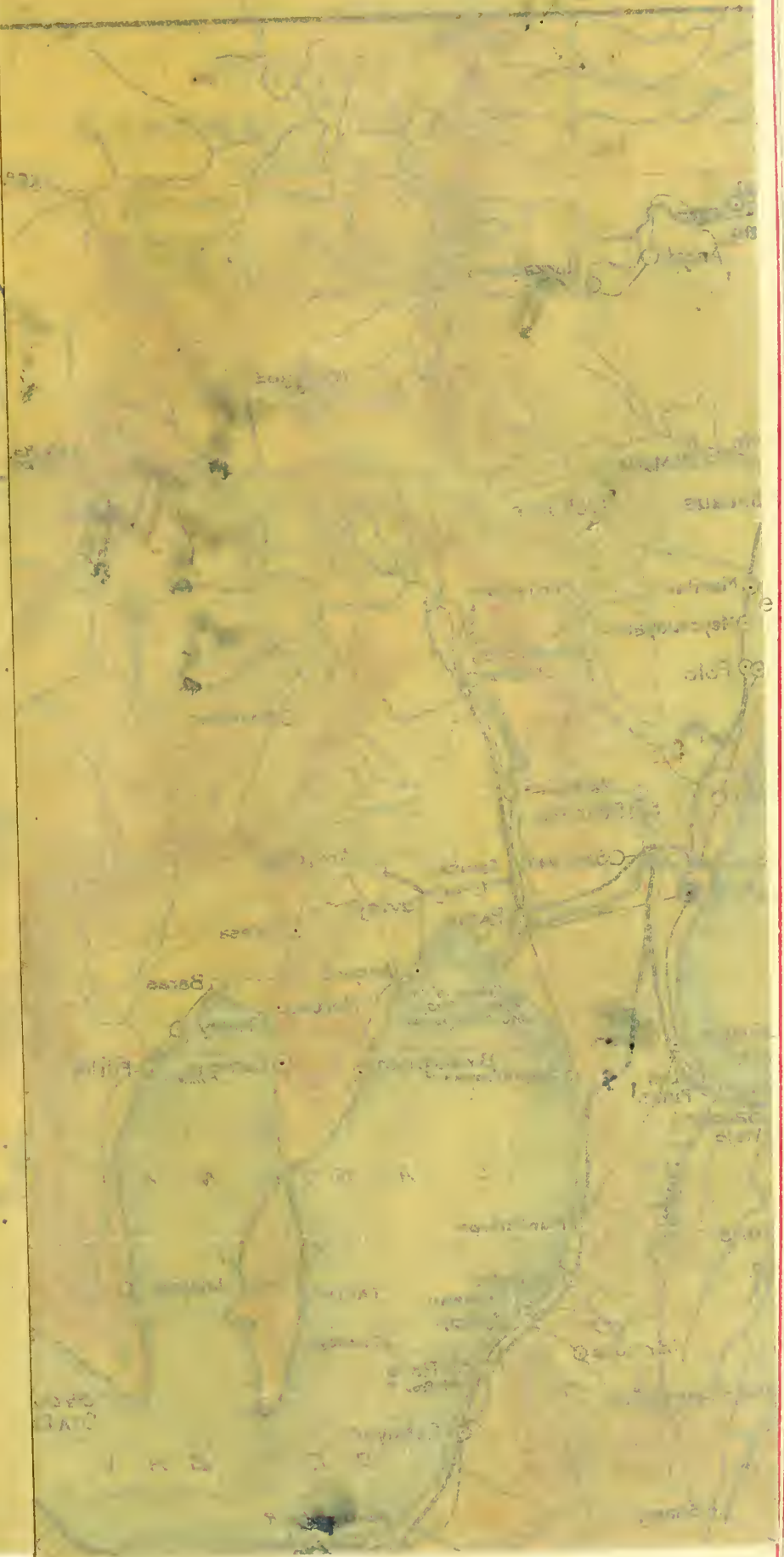
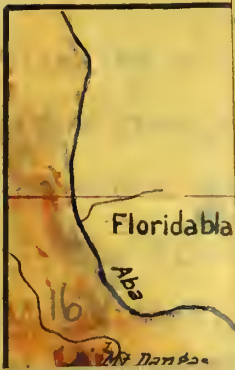
The rivers present similar aspects in all this country. They head in a few large or many small springs near the upper edge

of the foot hills, flow in deep, rocky beds thru the latter, and gradually rise up to the country level, until near their mouths their gradients become very low and their beds friable and unstable. Tide water does not generally extend up the Cavite rivers more than a mile. They afford every opportunity for the utilization of their flow for irrigation, and for the various methods described hereafter for diverting it. Probably no equal tract is more fortunately situated for the purpose than those lands were for the purposes of their clerical owners.

CLIMATIC. Rev. Jose Algue, Director of the Philippine Weather Bureau, has divided the Island of Luzon into three districts depending on the beneficence of their climates. This division is effected by tabulating the percentages of rain falling in the various months, the result being as follows:- (1) the worst climates are where over 80 per cent of the annual rainfall occurs in the five summer months, (2) some climates have only three or four months of drought, (3) the best climates have a more or less uniform distribution of rainfall.

The accompanying diagram, Plate IV, page 32a, shows the average total rainfall and the average season percentages in six districts into which Luzon can be divided by the above criteria. (1) The northern valley of the Cagayan River, (2) the northern Cordillera and their western slopes, (3) the Central Valley, (4) the western slope of the Zambal and Bataan mountains, (5) the interior plains surrounding Manila, and (6) the south-eastern peninsula of Luzon.

According to the authority above cited the most benefic-



Compiled by S.G. Cutler from ~
maps by U.S.C. & G.S. Military In-
formation Division, and Provincial ~
Surveys

Scale 1:400,000
MILEMETERS

10
PLATE

To accompany treatise by S.G.Cutler.



ficial climates occur in districts 1 and 6. The former is well known as the greatest tobacco raising district in the Islands, and the latter where its very rugged nature allows produces very fine hemp. In the first district was situated the large undeveloped estate of Isabella, which was too distant from Manila to be considered of value except for tobacco. Districts 3 and 5 group together and have similar climates which would come under the second class. Their proximity to Manila and the great stretches of agricultural land within them easily make them of greater practical value than the first mentioned lands. In these districts are found the principal agricultural estates, district 3 containing the numerous haciendas of Bulacan and 5 the tracts which we have under consideration.

Districts 2 and 4 have the worst climates, and the Friars did not take up land in them. The annual typhoons, passing from across the China Sea and meeting the mountains, drop most of their flood on the western slopes, causing excessive rainfall in that season; while the winter monsoon storms coming from the north-east lose their water in passing over the intervening ranges. The districts presenting the best climates show just the opposite topographic conditions, i.e., protection from the heavy, continuous autumnal rains and exposure to the lighter winter downfall. The southeastern end of Luzon is covered to the south-west by numerous islands rising high enough to break the force of the storms, while the north-eastern coast is the open Pacific. The Cagayan valley is protected by the great Cordillera to the south-west and open to the north-east. The ranges to the south and east of the Central Valley are not high nor broad enough to protect the country to any

great extent from the cyclonic storms, while the Cordillera intercept a good many of the monsoon rains; therefore the climate is midway between the other two. However it will be noted that in the actual amount of autumn rainfall, the Central Valley presents a minimum. In investigating the rainfall in the district 5 itself it is observed that the nearer the south-eastern ranges are approached, the greater and more concentrated becomes the rainfall. In the autumn season heavy rains are continuous on the northern slope of Mt. Maquiling, while Calamba may escape many of them.

Few general deductions can be drawn from rainfall charts of such meagre data and for so short a period. It will be noted however that Biñan and Cavite (town) in the lowlands show in general a longer continuation of the rains. Thus in Silang in the foothills over 80 per cent of the rain fell from May to September inclusive, in Biñan the same percentage required from May to October, and in Cavite from June to November.

In taking up particular instances of drainage and stream flow hereafter, there will be occasion to refer to what little rainfall data are obtainable.

PART II. GENERAL ENGINEERING FEATURES.

EXTENT OF THE ESTATES.

CAVITE. The Cavite Friar Land Estates lie in a roughly triangular shape, being bounded to the east by the provincial boundary of Rizal, about 25 km. long; on the south by various rivers connected by surveyed lines; this side being about 30 km. in length; and on the north-west by the shore of Manila Bay. See Plate V, page 36, for a map of the territory. They are divided from each other in most instances by the largest of the watercourses. The relative size and importance of the estates increases from those further away to those nearer Manila. Table I, page 37 shows their various areas.

If a median line be drawn thru the triangle bisecting its eastern side, very little rice cultivation will be found in the southern portion thus formed. The main irrigation diversions all lie very close to this line. North of it there is also of course much irrigated land lying in isolated strips and patches between the rice fields.

The estimation of the amount of irrigated land in these estates is difficult to make, and altho it has been made at various times the results do not agree very well. The Bureau of Lands makes classifications which are in many cases at fault, including more or less land than it is possible to irrigate from the present works. A table is inserted herein showing the approximate areas under irrigation and those under cultivation. This table gives an irrigated area in Cavite of 10500 ht. or 22 % of the total extent

To accompany treatise by S.G. Cutler.



Table 1. The Larger Friar Land Dams.

| Name | Stream | Purpose | Area | Length | | Height | Width Crest | Profile | | Batter | |
|--------------------------|---------------|---------|--------|--------|---------------------|--------|----------------|---------------------------------|--------------------|--------------------|-----------------|
| | | | | Total | Spillway | | | D'wns'm | Ups'm | D'wns'm | Ups'm |
| NAIC | | | | | | | | | | | |
| Balayungan | Balayungan | 1 | 1 | | 150 | 25 | 12 | Ogee | | $\frac{3}{4}:1$ | |
| Calumpang | Caysaba | 1 | 2 | | 100 | 40 | 20 | Str. | | 5:12 | |
| Culong-culong | | 2 | 1 | | 120 | 25 | | Stepped | | | |
| STA CRUZ DE MALABON | | | | | | | | | | | |
| Tres Cruces | Maralin | 3-4 | 4 | 730 | $\frac{1-75}{1-40}$ | 65 | | Straight | | $\frac{1}{4}:1$ | |
| Legidero | Catibayo | 5 | 5 | 300 | | 15 | 4 | | | | |
| Singo | Obispo | 5 | 5 | 300 | 40 | 20 | 6 | | | $\frac{1}{2}:1$ | |
| Pajo | | 5 | 5 | 350 | | 20 | 6 | | | | |
| Molino Sta Cruz | Cañas | 1 | 6 | | 120 | 40 | 45 | | | | |
| SAN FRANCISCO DE MALABON | | | | | | | | | | | |
| Bancod | Naic | 1 | 7 | | 70 | 40 | 10 | Ogee | | | |
| Palauit | Panisayen | 1-3 | 7 | | 50 | 80 | 5 | Ogee | | | |
| Buloc | Matangilan | 1-6 | 7 | 180 | 27 | 50 | 5 | Straight curved at bottom | Stepped | | |
| Ladron | Ualan | 1 | 8 | 220 | 22 | | 4 | | | | |
| Pason Bato | Calubcub | 7 | 8 | | 30 | 25 | 3 | Ogee | | | |
| Marcelo | Ilanilan | 1 | 9 | 100 | 50 | 30 | 6 | | | | |
| Sampalucan | Ilat ng paldo | 1 | | 180 | 36 | 20 | 6 | Straight | | | |
| Policena | Cañas | 8 | 10 | 143 | 110 | 50 | 15 | Ogee | Stepped | | Stepped |
| Antigo | Ualan | 8 | 10 | | 100 | 30 | 3 | | | | |
| IMUS | | | | | | | | | | | |
| San Agustin | Ilanilan | 1 | 11 | | 55 | 22 | 10 | | | $\frac{3}{4}:1$ | 1:1 |
| Nancaan | Nancaan | 1-3 | 11 | | 50 | 22 | 5 | | | 1:1 | |
| Jasaan | Jasaan | 1-6 | 11 | | 50 | 20 | | Straight | | Nearly vertical | |
| Casundit | Casundit | 6-8 | 11 | | 75 | 25 | 30 | Stepped | | $\frac{1}{2}:1$ | $\frac{1}{2}:1$ |
| Lugsujin | Casundit | 1 | 13 | 240 | 75 | 26 | 12 | | | | |
| Das Mariñas | Casundit | 8 | 13 | | 60 | 25 | 7 | | | $\frac{1}{2}:1$ | |
| Trapiche | Tibagan | 1 | 14 | | 200 | 28 | 12 | | | | |
| Salitran | Tibagan | 1-8 | | 150 | | 20 | | | | | |
| Baluctot | San Cristobal | 1 | 15 | 100 | 60 | 25 | 6 | | | | |
| Embarcadero | Malaguin-ilog | 1 | 18 | 200 | 140 | 60 | 15 | Stepped at Straight | | $\frac{1}{2}:1$ | |
| Pason Buya | Pasonbuya | 8 | 16 | 275 | 120 | 25 | 3 | | | $\frac{1}{2}:1$ | |
| Bocal | Palico | 8 | | | 80 | 15 | 10 | | | | |
| Molino | Zapote | 1-4-8 | 17 | 900 | 200 | 50 | 10-16 | Straight | Vertical | | |
| Ligas | Zapote | 1 | Others | | 150 | 40 | 15 | Ogee | | | |
| Tansang Luma | Imus | 8 | | | 130 | 8 | 6 | Straight | Vertical | $\frac{1}{2}:1$ | Vertical |
| Julian | Julian | 8 | | | 80 | 20 | | Stepped | | $\frac{1}{2}:1$ | |
| Pason Castila | Ilanilan | 1-8 | 12 | | 100 | 26 | 18 | Straight | | $\frac{3}{4}:1$ | |
| Afapan | Alapan | 8 | | | 75 | 15 | 8 | Ogee | | $\frac{1}{2}:1$ | |
| SANTA ROSA | | | | | | | | | | | |
| Dismo | Dismo | 1 | 22 | | 100 | 20 | 3 | Offset Block | Nearly Vertical | | |
| CALAMBA | | | | | | | | | | | |
| Campaña | San Cristobal | 1 | 23 | 150 | 70 | 46 | 15 | Slightly Curved | Straight | $\frac{1}{4}:1$ | $\frac{1}{4}:1$ |
| San Juan | San Juan | 1 | 24 | 350 | 200 | 45 | 7 | Offset straight | Offset Straight | 1:1 | $\frac{1}{2}:1$ |

* Explanation of figures in this column

- 1 Primary Diversion 5 Concentration
 2 Reinforcement 6 Tertiary Diversion
 3 Secondary Diversion 7 Passing Sub Drainage
 4 Storage 8 Drainage Rediversion

† Refer to numbers on Plate 21

All dimensions are in feet, as the reader can thus
 obtain a more ready idea of the sizes.

Some data taken from Report B. Engineering 1905.

Table 1. The Larger Filar Land Dams

| Name | Stream | Number | Area | Length | | Height | Width | Profile | Bottom | Slope | Area | Volume |
|---------------|---------------|--------|--------|--------|----------|--------|-------|----------|--------|-------|------|--------|
| | | | | Total | Spillway | | | | | | | |
| Alapah | Alapah | 8 | 1-8 | 75 | 12 | 12 | 8 | Dec | 18 | 18 | 18 | 18 |
| Parson Castle | Indian | 1-8 | 15 | 100 | 20 | 20 | 18 | Steep | 18 | 18 | 18 | 18 |
| Julien | Indian | 8 | 8 | 80 | 20 | 20 | 18 | Steep | 18 | 18 | 18 | 18 |
| Tansang Luma | Imus | 8 | 8 | 130 | 8 | 8 | 12 | Steep | 12 | 12 | 12 | 12 |
| Ligas | Expos | 1 | others | 130 | 40 | 40 | 12 | Open | 12 | 12 | 12 | 12 |
| Molino | Expos | 1-8 | 17 | 200 | 200 | 20 | 10-18 | Steep | 18 | 18 | 18 | 18 |
| Bocal | Polio | 8 | 8 | 80 | 12 | 12 | 10 | Vertical | 10 | 10 | 10 | 10 |
| Parson Buys | Paradise | 8 | 12 | 272 | 150 | 32 | 3 | Steep | 12 | 12 | 12 | 12 |
| Embarcadero | Malaga-Ind | 1 | 18 | 200 | 140 | 40 | 12 | Steep | 12 | 12 | 12 | 12 |
| Balchast | San Cristobal | 1 | 12 | 100 | 40 | 22 | 6 | Steep | 12 | 12 | 12 | 12 |
| Saltan | Tibagan | 1-8 | 14 | 150 | 20 | 20 | 10 | Open | 10 | 10 | 10 | 10 |
| Tropic | Tibagan | 1 | 14 | 200 | 28 | 28 | 12 | Dec | 12 | 12 | 12 | 12 |
| Las Marias | Carandit | 8 | 13 | 60 | 22 | 22 | 7 | Steep | 7 | 7 | 7 | 7 |
| Luzujin | Carandit | 1 | 13 | 240 | 22 | 22 | 12 | Steep | 12 | 12 | 12 | 12 |
| Carandit | Carandit | 6-8 | 11 | 72 | 22 | 22 | 30 | Steep | 30 | 30 | 30 | 30 |
| Jasanan | Jasanan | 1-6 | 11 | 20 | 20 | 20 | 2 | Steep | 2 | 2 | 2 | 2 |
| Manoran | Manoran | 1-3 | 11 | 20 | 22 | 22 | 2 | Steep | 2 | 2 | 2 | 2 |
| San Agustín | Indian | 1 | 11 | 22 | 22 | 22 | 10 | Steep | 10 | 10 | 10 | 10 |

| | | | |
|---|--------------------|---|---|
| 4 | Storage | 8 | Waste Reversion |
| 3 | Secondary Division | 7 | Passing Sub Division |
| 2 | Reinforcement | 6 | Tertiary Division |
| 1 | Primary Division | 5 | Concentration |
| | | | * Explanation of figures in this column |

Some data taken from Robert & Engineering 1902.
obtain a more ready idea of the sizes.
All dimensions are in feet, as the reader can find
refer to numbers on Page 51

of those estates, 52 per cent being regarded as under cultivation. The writer believes from what he has seen of the lands that the latter proportion is high. There are enormous quantities of waste lands in the estates. The writer from various maps which are based on surveys has compiled a table of irrigated areas, inserted later, which gives a total of 18,500 ht. Of course, at the time the former estimate was made, several of the systems were not in use, and have since been rehabilitated.

In the first evaluation of the estates 22,582 ht. were designated as first and second class rice land, which is generally construed to mean land under irrigation for two seasons or for one season, respectively. It is impossible to state how much land is irrigated for one season only, since that as often depends on the inclination of the landholder as on the available supply. Any fine degree of accuracy is unjustifiable, owing to the constant change in the amount of land supplied, and the writers figures are believed to be within reasonable bounds.

The estates are traversed by various main trails: (1) from the river mouth at Zapote past the old hacienda building of San Nicolas, Imus, and thence southward thru the irrigated land to the barrio Paliparan; (2) from Imus connecting with the above at San Nicolas; (3) from Bacoor on the Bay thru Imus and the irrigated lands south-west to Perezdasmarrinas and Silang; (4) from Noveleta near the Bay to San Francisco de Malabon, and thru the irrigated lands south to Buenavista and beyond; (5) from Rosario on the Bay to San Francisco de Malabon; (6) south from Sta Cruz to Indang; and (7) from Naic to Indang. These all run approximately north and south, parallel to the drainage. Various small and almost impas-

sible cross drainage trails exist, giving access to the dams and to the irrigated lands not adjacent to the main trails.

It will be seen from the above lines of traffic that a great amount of the produce passed thru Imus, this town being fortunately situated in other ways, being the largest in the province outside of Cavite proper. The Imus River is navigable for small craft at high tide as far up as the town, but most of the shipping is done at Zapote and Bacoor. San Francisco de Malabon is not so large, all produce passing thru it to Noveleta and Rosario. The latter town and Sta Cruz, are both small. Naic is quite large, and can be reached from the Bay. It derives a good deal of importance however as a transit point to Indang and Silang. All the Cavite towns suffered greatly during the insurrection, and were once very well built places. San Francisco and Imus have the largest local markets.

LA LAGUNA. The Laguna estates, together with the Municipality of Cabuyao, lie in a triangle bounded on the south by 20 km. of the Batangas line, on the north-west by 23 km. of Cavite line, and on the north-east by Laguna de Bay. The Biñan estate comes within 3 km. of the Imus estate at its most northern point. Of these estates the Calamba is much the largest, but is unimportant from an irrigation standpoint. The Sta Rosa and Biñan estates are of about equal importance. Besides those in Laguna province, the Muntinlupa estate, unirrigated, in Rizal province spans the gap between the Imus estate and Laguna de Bay. The Municipality of Cabuyao lies between the Calamba and the Sta Rosa estates, while the former estate and Biñan adjoin.

The writer estimates that about 4050 ht. or 17 per cent

of the Laguna estates are irrigated, this percentage being low on account of Calamba, of which only about 7 per cent is irrigated. In the first classification 9223 ht. were adjudged first and second class rice land. The irrigated land lies in a strip along Laguna de Bay, approximately six kilometers wide, altho narrower in Calamba. The first estimate of irrigated land in Calamba as made by Mr. M. Dobbins was 966 ht., grounded on a detailed survey. Since that about 140 ht. more have been irrigated. The figures given for Sta Rosa were computed from a detailed survey by the writer in 1909.

The estates are all connected by what has been a fairly good road -- parallel to Laguna de Bay and from one to two kilometers distant from it. This is soon to be connected so as to form a continuous road from Manila. From this road trails run at right angles from Muntinlupa to Imus, from Biñan to Carmona and Silang, and from Sta Rosa thru barrio Sto Domingo to Silang. Numerous small trails parallel this and the drainage.

The largest town is Calamba, which in Spanish times gained its importance as a transshipping point for the country south of it. It had the largest market of any town in the province. Biñan is also an old and formerly important place, being at the beginning of the most traveled trail to Cavite; and on this account it became an insurrecto headquarters, and the Friars were expelled at an early date. The insurrectos were also active in Calamba, whose landlords were supposed to have occasioned more grievances than any of the others.

Each of the Laguna towns served as its own shipping point. Of late the railroad has decreased the commerce in these towns,

Calamba especially having suffered from the present thru rating of freight from the south.

HYDROGRAPHY.

CHARACTER OF THE DRAINAGE. The streams of this part of the two provinces lie in a fan shape, their general common source being the Taal range of mountains on the Cavite-Batangas line between Mt. Sungay (740 meters) on the east and Mt. Batulao (810 meters) on the west. Beginning in mountain ravines the water gathers into creeks flowing in canyonous beds, these ravines being from 50 to 80 meters deep in the upper foot hills. It is however lower down, where these ravines have somewhat consolidated and are not more than 20 to 40 meters deep, that the primary diversions are made.

Below the foot hills the beds change somewhat in character, and the country rock shows only occasionally. In general the beds are from 5 to 10 meters deep and the banks are well weathered rock or clay. It is at this point that the diverted and drainage water from the primary irrigation works begins to find its way back into the channels, and that secondary diversions are made. It is useless to attempt below these latter to systematize any hydrographic data, the original supply and the field drainage being so intermixed.

Still further down, the rivers reach tide level, and flow very slowly in beds 2 or 3 meters deep, in friable soil. At this point the greatest amount of drainage water enters. Still further down the land itself sinks to base level, and the irrigated fields

give way, in Cavite to salt flats and in Laguna to mud flats thru which the rivers wander in deltaic channels to their mouths.

Within the estates the drainage descends thru eleven main channels, which are detailed on Plate IV, page 33. The Balayungan and Naic Rivers, in the Naic estate, flow towards the north-west, as does the Timalan, a small stream draining the interior of Sta Cruz. The Cañas, the main branch of which forms the boundary between Sta Cruz and San Francisco, the Ilanilan, the largest river in Cavite, lying between San Francisco and Imus, the Imus, and the Zapote, the eastern boundary of Cavite all flow nearly south into Manila Bay.

In Laguna the headwaters of the Biñan, which flows north-east, adjoin those of the Zapote and Imus; the Sta Rosa comes next, parallel to the former; the San Cristobal, a large stream, radiates from the same mountain (Mt. Sungay) as the Imus, flowing entirely thru Calamba. The San Juan River, the largest of all, does not originate on the same ridge as the others, but drains a bed between that ridge and Mt. Maquiling, flowing in a nearly southerly direction.

SEASONAL RAINFALL. During about five months the amount of water falling in the district is practically nil, the streams obtaining what water they have from seepage and springs. Roughly this season may be said to be from January to May inclusive, altho it is not as is believed by foreigners unchangeable. The springs are numerous -- probably there are few places in the world where streams of so small a drainage area flow steadily thru so long a period of drought. They do however often sink perilously low --

the dry season supply is seldom considered infallible, and it may be a matter of wisdom that so little land is cultivated in that period. About the middle of June the rains start, occurring each day for weeks at a time. They are not especially heavy during the first four months, but the aggregate is large. The effect on the streams is gradual -- the ground needs a good deal of water to saturate it after its long drought, but gradually the discharge increases. The writer is of the opinion that at the close of the rainy season the average fair weather run-off has more than doubled in these streams.

The rains above mentioned must be distinguished from the cyclonic rains accompanying the typhoons. After about four months of pretty steady rain the weather changes, and there are quite lengthy stretches of fair weather; but about every two weeks cyclonic storms sweep the country, during which for two or three days immense quantities of rain fall. Each time of course the ground is soon saturated, and the excess water swells the streams out of all proportion to their usual discharge, this in small streams being often in a ratio of several thousand. After these downpours the discharge rapidly drops to the average for that season. The floods are of course not a help, but a menace, to the irrigation of the country.

During very exceptionally long droughts, the springs may fail -- a circumstance which the writer has heard of, but never seen. This "lower low water" occurs seldom and need hardly be considered. For about five months, or for the sake of simplicity six months, occurs "mean low water", on which stage depends the most important or dry season irrigation. During the remainder of

the year occurs "mean high water". At this stage the irrigation works serve more as storage and distribution facilities than as supplies. During some twenty days in this period occurs "flood stage", when the only duty of the irrigation works is to hold against the attacks of the rivers and drain the country rapidly.

STREAM DATA. Accurate data for these streams is not to be had. A few approximations are however available, which must of necessity be used. The Government is at present installing many stream gages, and the approximations will soon be obsolete.

Mr. Dobbins reports that in June, 1905 (m.l.w.) the total quantity reaching the San Juan dam at the head of irrigation in Calamba was 891 lrs. sec. This river above the dam has a drainage area of 255 sq. km. which would correspond to a flow off of 3.5 sec. lrs. per sq. km., or 0.3 mm. depth in one day. By consulting the rainfall chart previously given for this vicinity we find an average daily depth in the dry season of 0.907 mm. It would thus appear that about 34 per cent of the rainfall flows off, a fairly average value for this season and class of topography. The writer in January, 1911, (beginning of m.l.w.) made gagings at the same place of 1355 sec. lrs., or 5.3 sec. lrs. per sq. km. which agrees fairly with the foregoing.

Mr. Dobbins also estimated from high water marks that the maximum discharge of the same river was 390,540 sec. lrs., corresponding to 1530 sec. lrs. per sq. km., or a daily depth of 132 mm. This is by no means unusual when one considers the nature of the cyclonic rains in the Islands and when compared to corresponding results for other tropical countries. At such times probably nearly the total volume of the heaviest rain flows off within a few

hours. The same authority gives a gaging of the San Cristobal River at the Campana dam to be 979 sec. lrs. in July, 1905; and he estimates the minimum to be 783 sec. lrs. This on a drainage area of only 33 sq. km. is at the rate of 24 sec. lrs. per sq. km., or a daily depth of 1.9 mm. The same authority gives from high water observations on this river a maximum discharge of 707,500 sec. lrs., corresponding to 21,400 sec. lrs. per sq. km. Both of these results seem exceptionally high. The writer has identified the points on the dam which Mr. Dobbins assumes are high water points, and does not believe the level ever rises to them. Altho the writer has never gaged the river at that point, he visited it in January, 1911, when he is quite sure there was not a flow of 500 lrs. However, this river is supplied by several very large springs, and has undoubtedly a larger flow than would be supposed from the map.

The writer has observed the Dismo River on many occasions, and its m.l.w. discharge, which hardly varies for months at a time, is 400 sec. lrs. Its drainage area is 35 sq. km., which gives a runoff of 11 sec. lrs. per sq. km. or a depth of 0.952 mm. per day - about equal to the dry season rainfall. This river is also partly supplied by springs. From high water data gathered by the writer, he estimates a maximum discharge of 81,600 sec. lrs., or 2330 sec. lrs. per sq. km., a daily depth of 182 mm. These results agree well with those previously cited for the San Juan River, considering the relative sizes of the streams. Practically the same minimum discharge was observed on the Sta Rosa River, a similar stream, with the same drainage area.

Mr. Mulder obtained a discharge of 2009 sec. lrs. in October, on the Balayungan River in Naic, Cavite. He estimates the

minimum discharge to be 1000 sec. lrs., which would be 16 sec. lrs. per sq. km. of drainage ares. This estimate seems high for so large a stream.

These random and inaccurate data are of little use, but unfortunately they are all we possess at present, and perhaps considering the annual variations they will be as valuable as the gage records of but a few years. It appears that the dry season runoff varies from 3 sec. lrs. per sq. km. to 10 sec. lrs. per sq. km., in the larger and smaller streams respectively. The reason for this is not difficult to detect. The earth takes every drop it can in this season, and the longer the watercourses the more chance there is for permanent seepage. Also in large areas the effect of springs is smaller in relation to that of percolating water in aggregating the discharge, than in the small ones. The above figures will be used as a general basis for following discussions.

UTILIZATION OF FLOWOFF. It will be seen that out of a total drainage area of 1144 sq. km., 789 sq. km. or 69 per cent is commanded by irrigation works. Omitting the San Juan River, the relation of the tributary area to the necessary supply of which is out of all proportion to that obtaining elsewhere, the total drainage area remaining is 880 sq. km. of which 534 sq. km. or 61 per cent can be utilized for irrigation. It can be seen that at the duty rates used this would at best irrigate only some two or three thousand hectares. It will be interesting to note how this bears on the irrigation units severally.

During the rainy season there is no lack of water at any time. According to rainfall data some 3000 mm. fall in 180 days. Suppose there are ten days during this period when the 70 per cent

discharge is 100 mm. per day. This would account for 1430 mm. of rainfall. The remaining 1570 mm. at a 50 per cent discharge would give 4.6 mm. per day for the entire period, a supply of 50 sec. lrs. per sq. km. This would supply the entire area, neglecting the floods -- which hardly occupy the time cited even.

Altho the streams of the Friar Lands are too numerous to gage completely -- about 200 gages would be necessary to do that, the hydrographic study of say, one estate, with a view to learning during what season various supplies can be expected, is a consummation to be desired.

TOPOGRAPHY.

DIVERSIONS. A good deal has been said in various portions of this paper about the topography of this country in general, and it now remains to describe in detail, some of the conditions found in the vicinity of the irrigation systems.

The Friars seldom neglected one precaution -- to allow an ample height of river bed above the crest of their primary diversion dams, thus guarding against side cutting during floods. These dams were generally built in rock canyons, from 20 to 30 meters deep, and reached a point some ten meters from the tops of the gorges. The rivers are generally steeply banked within that portion of the beds, above which more gradual slopes begin. They generally have longitudinal bed slopes of between 1:100 and 1:500, down equal or slightly greater ground slopes.

Both in Cavite and Laguna one very favorable condition obtains the subdrainage channels run parallel to rather than at right angles to the main streams, and taking a section perpendicular to

one of the latter its own banks are the highest points on the section. Thus ample protection is offered against floods, which never top the banks and are thus barred from the surrounding country; and when these banks are once passed over or under, it is an exceptionally easy matter to find a good line for a canal or tunnel.

In very few instances do the river beds at main diversions allow for the taking off of open-cut canals without inserting a very high and consequently dangerous dam. In a few cases a site has been chosen for the dam where a shelf occurs some distance below the top of the gorge, which widens out downstream and allows a canal to gain the country level along it. This is the case at the San Juan dam, Calamba, the old Dismo dam, Sta Rosa, and the Tres Cruces dam, Sta Cruz -- none of which are however in very deep gorges.

Generally no such diversion is possible without sacrificing the security of a certain depth of gorge above the dam crest, and in such cases labor being cheap as compared to materials, the Friars turned to tunnels. Flumes used to lead water out along the canyon walls were unknown. The tunnels were generally headed for some subdrainage line down which the water could be led to the land, and their direction was a happy medium between the most rapid country slope and the nearest line to the watercourse in view. Often other streams were crossed and often gone under in the process of tunneling. Where the supplying stream was the main one and only its own tributaries were crossed, the tunnel was in general deepest near its beginning, but where as in the case of the Bancod tunnel other entirely independant streams were passed, there was no special rule followed.

The subdrainage lines, being as has been previously noted in shallower beds than the main streams, generally offered favorable opportunity for re-diversion directly to the surface. There was little danger in the smaller streams from floods, so the dams were built very nearly as high as the banks. These secondary diversions were generally made at some point where a rapid drop in the country offered opportunity for reaching it with a canal immediately. The drainage beds dammed averaged 5 to 10 meters deep and were generally 20 to 40 meters across at crest level. Owing to the relative height to which these secondary dams were built, they required wing walls in every case.

DISTRIBUTION. The writer has seen numbers of small dams so situated that water flowed directly thru a gap in the wing wall onto the irrigated fields. Where main canals of any length were used below secondary diversions, it was generally to pass higher ground lying between the dam and a portion of the land to be irrigated, and sometimes tunnels were again used for the same purpose.

The irrigated land in all cases is broken up at intervals by nearly parallel ravines or sloughs, in the higher and lower lands respectively. Between these the country is nearly level, generally having some slope upward toward the bank of the creek lying nearer to the main stream. It is generally the custom to lead a canal across this field drainage, providing spillways below each crossing and allowing the creeks to serve as laterals, or closing them completely and running laterals between them, if any intervening ridge is perceptible. Many of these high-line creeks may have formerly been canals, since they occur so often and are in a location where

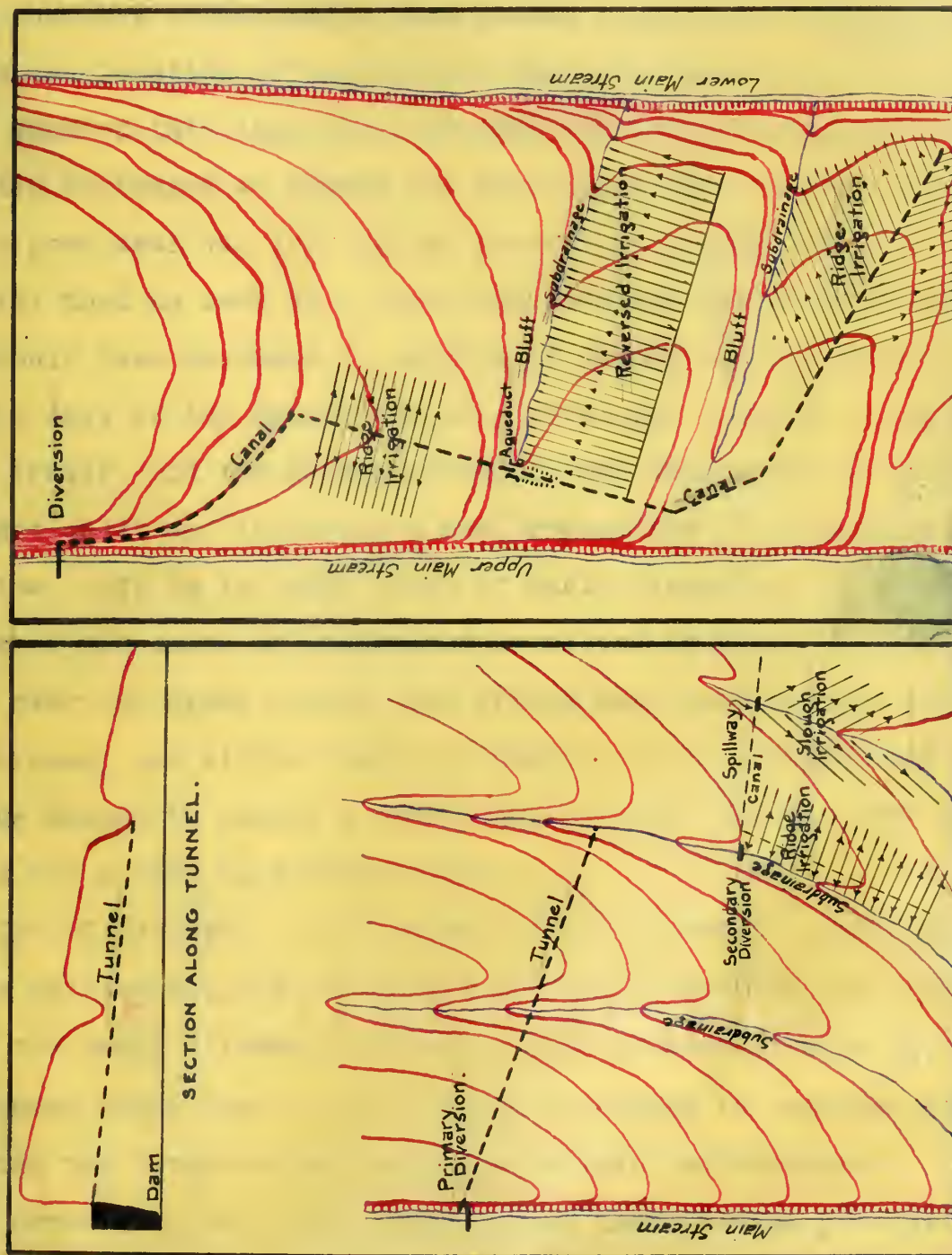
naturally so little drainage water would reach them. These creeks are from one to four meters deep, and from one to five wide.

Parallel to the creeks the slope of the country varies gradually from about 1:200 at the toe of the foot hills to 1:100 in the lowlands. In the latter the cross section of the country also becomes more nearly level, so that it makes little difference whether the supply is from a ditch on one side or a ditch on the other. In some places, always in the neighborhood of rivers, the land rises in steps, but the top of each step is higher than the bottom of the next higher one. The depression thus formed slopes down, parallel to the steps, and away from the nearest river. This formation is very trying to the irrigator, and was generally met by spanning the depression with a masonry aqueduct or heavy fill and leading the irrigation water back in a reversed direction across the fields. This condition, as well as others discussed, it has been attempted to show on Plate VI, page 51.

DEVELOPMENT OF IRRIGATION.

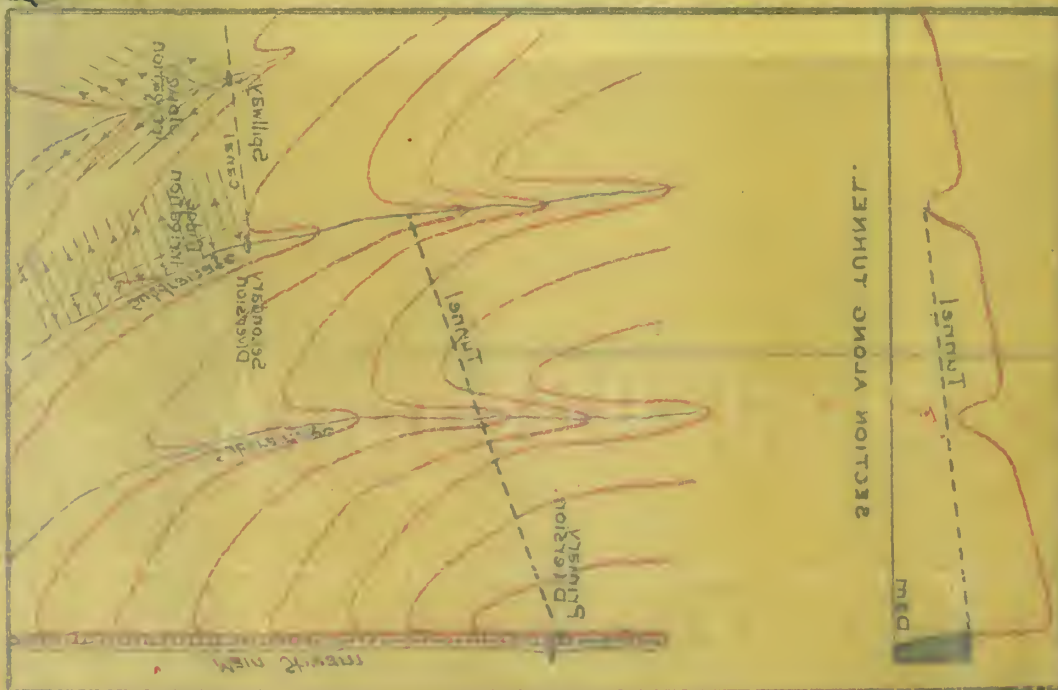
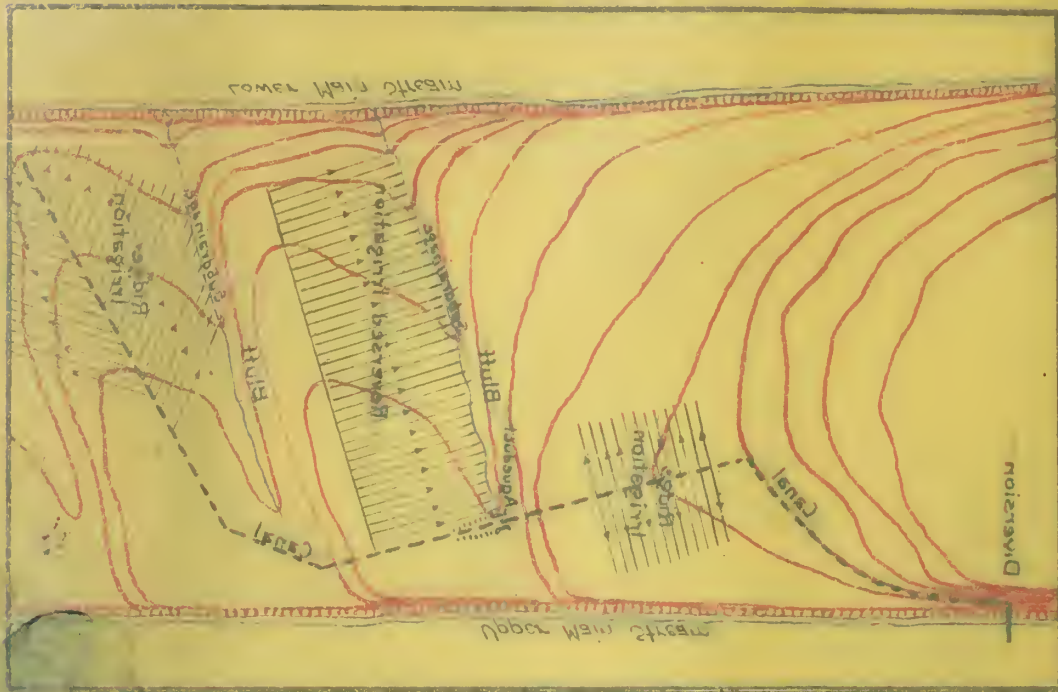
In the three previous articles of this section, it has been attempted to give some idea of the problems usually taken up in the investigation of an irrigation system. The writer will now discuss the relative regard given by the Friars to these various items in designing their systems.

EXPLORATORY. The first diversions made by the early Spanish estate holders were undoubtedly haphazard ones made to turn water onto the land in the immediate vicinities of the haciendas, and were merely replacements of native dams, existing or having existed. At this time there was no idea of the amount of land available, the



TYPICAL DIAGRAM MAPS SHOWING
METHODS OF IRRIGATION

To accompany treatise by
S. G. Cutler



water being merely intended for small tracts already cultivated.

The towns, which were later highly developed, started with collections of huts about the convents of the Order and the hacienda houses of the owner. The outlying barrios were delegated to various friars, who of necessity traveled the trails to the controlling churches occasionally, and became conversant with the capabilities and location of the various tracts of land in their district. Much of this land could be obtained for a pittance, much was heavily mortgaged to uphold the gambling propensities of the owners, a good deal was left to the Orders by bequests; and it was but natural that as soon as a tract was obtained the foresighted Friars should take measures to improve or accomplish its irrigation. Before the days of the Friars the only developed land lay along the outlying trails, and the matter of supply was merely one of finding the nearest creek and inserting a dam, regardless of topography or stream flow. It is in those cases of early diversion, that we find most of the cases of undermined or silted up dams. As they traveled over the upper trails, the Friars must have crossed the larger streams, and without any very definite data decided that they were large enough to supply a great deal of land; but the cost of works was for a long time prohibitive.

INVESTIGATIONS. As time went on the estates became more generally cultivated, and the demand for water exceeded the capacities of the small streams utilized. Many diversions were left dry by others above them, and it became necessary to consider means of reaching the larger water courses to obtain reinforcement.

Several of the dams placed in the large rivers were destroyed, and the Friars learned by experience that the methods

which had been used in the creeks were not applicable. They therefore started the system of tunneling, so much used later. The fact that those early tunnels invariably run down country, in spite of the extra distance entailed, and that they invariably reach the country level further up than they are used for irrigation, shows one of two things -- either that the investigation did not go to the extent of instrument work to determine the best available line or that the system was planned for more land than was afterwards supplied. The former is probably the case -- they wished to be sure of the water.

The investigation of the supplying stream probably took note of three points: (1) the relative amount of water, i.e., whether the river seemed large or small; (2) the nature of the bed, i.e., the relative advantages for dams -- height of bank, width of section, kind of bank lining; (3) the water right. All these points were mentioned in the first official reports by the Orders relative to new works, but not quantitatively until later.

Knowing as little as they did regarding the extent of the land to be irrigated, closer investigations would have been useless. They took what water was available, and took it from the largest stream they could find. This settled, the next problem was to get the supply to the place needed, and the natural answer was to empty the water into the creek leading to the old dam which they wished to reinforce. It is quite evident, especially in the case of the Bancod tunnel, the longest, that by putting their works in lower they could have saved labor, since the discharge of this tunnel is nearly ten meters higher than the river bed it enters. By so doing the three aqueducts could have been much reduced in height.

It was probably at this time, when the Friars began to learn how costly irrigation was, that they first entertained the idea of enlarging their units so as to give a larger return, and this idea must have done much towards developing exortionary methods. A good deal of land was occupied thru foreclosure, which the Friars either by diligence or irrigation made profitable. This "boom in irrigated lands" occasioned the improvement of methods of investigation, and we begin to find reports mentioning definite quantities, areas, and duties.

It was the shortage thus caused which occasioned the development of ideas of storage, as exemplified at Molino; of consolidation, as at Tres Cruces and Legidero; and of long cross-country diversions as at Bancod and Campanã. The advantage of the drainage of a few extra hectares, or of a few extra meters of head, began to be understood. It is certain from the superiority of their execution that the most complicated systems were planned last.

Again, while acknowledging their boldness, the writer must state that none of his observations on their work, except perhaps on the dams, show any technical study beyond the most superficial. The storages and consolidations were made by rule of thumb, and their working is still largely a mystery, no proper maps or plans ever having been made. Canals were cut thru the upper country on grades of 1:200, while by reducing this and placing the dams lower down, many meters of line could have been saved. Tunnels, where the water was not needed immediately, were run at a grade of 1:300 going below water courses which could have been used, rather than by decreasing the grade and emptying into these creeks, saving one half or one third of the length. In other places in their eager-

ness to irrigate certain tracts the main lines were given so slight a grade that no water would flow. In general the opinion of the writer is that till a very recent date the only "rule" used was that "so large a river would irrigate so much land" regardless of the quantity of water in the latter.

WATER RIGHTS. In 1866 the Spanish government enacted its "Law of "Waters", and applied it to the Philippines. This was modified later however in such a way as to satisfactorily prevent the installation of works of appropriation on a river which entered land of another owner further down, and which was claimed by the lower landlord. This law as modified was entirely to the benefit of the large hacienda owners, and was doubtless intended to keep their supplies intact. It can be seen in a few instances now that this was a case of "dog in the manger"; but it is hard to blame the government in the state of knowledge at that time, for taking no chances in defining rights to certain quantities of water.

The Friars, with much land still capable of irrigation, can not be blamed for bitterly opposing any higher water appropriations. This is exemplified by the legal contest between the Dominicans of Calamba, and the Municipality of Tanauan, Batangas, over the right of the latter to divert water from the upper San Juan River. If the Dominicans then contemplated, as the writer thinks they did, the irrigation of their estate to its present extent, they were well justified as can be seen by referring to the following articles of this paper.

Several instructive instances can be seen in Cavite, illustrating the working of the law of waters between the various estates. The best example is the cross country appropriation of

the Bancod River by the Augustinians, above the Dominican estate of Naic. This was probably by agreement, in exchange for the diversion made by the latter in the Cañas River, which however for a time had been entirely in Augustinian territory, but which they had to cross without appropriating at the time of the building of the Bancod tunnel. Owing to the frequent changes in ownership of the various Cavite estates, the Cañas and Ilanilan Rivers must have caused almost constant litigation. Some idea of the nature of these complications will be seen in the paragraphs treating of the amount of the various supplies.

PART III. DETAILS OF DESIGN AND CONSTRUCTION.

DAMS. It is quite evident that the "anicut" type of dam, built on a porous or even unstable bottom, was never developed nor attempted by the early irrigators. They pursued the surer, if not so elastic, method of building on a rock bottom. As a general case we find their dams in such a locality and built to such a height that not only the bottom but the sides also are keyed to the country rock. Indeed in many places it is evident that if the safety of rock sides could have been neglected by the builders, a great deal of extensive tunnel could have been saved and much extra land irrigated.

It will be well to describe shortly the rock which is almost invariably both the foundation of the Friar dams and their material of construction. Guadelupe rock, known vulgarly as "adobe" both from its qualities and its resemblance to dried mud, is a volcanic tufa which underlay at varying depths the entire country under discussion. Generally soil-covered for a few feet on the agricultural lands, it outcrops in the hills and forms a fair foundation for headworks where most needed.

Adobe is of various appearances and consistencies, ranging from a very finely divided clayey rock with hardly any evidence of cinders, to a porous rather brittle mass of igneous boulders imbedded in a matrix of solidified cinders. The latter variety is generally hard, a pick striking fire on it and a blast blowing out a conelike mass backwards rather than a striking in. The softest grades can easily be indented by a heavy kick. Its specific gravity is low -- about 1.1 to 1.8. It is a dull stone of a greyish

brown color. It is stratified in beds of varying thickness, the thinner ones having the appearance of course slate. Those planes of stratification which appear near the surface are sources of great weakness structurally, admitting water under pressure which splits the over lying strata and gives rise to very numerous springs found in the rock. One of the most peculiar features of the rock is its behavior under exposure. Instead of breaking down in moist air as do some other volcanic conglomerates, that condition seems to have no effect on it, nor does the chemical action of clear water. Of course in exposed conditions weathering is rapid, especially since prolonged heat opens small cracks in it which fill with water -- much the same action as in clay. The action of running water is to coat the rock with a kind of yellow slime, not chemical, but having the appearance of a thin clay deposit, and altho this does not moss over its smooth surface seems to prevent erosion. Mechanical action, such as the passage of cart wheels, rapidly breaks and wears the rock into a smooth black mud, which returns to its original state if again left undisturbed. It will be seen that altho weak and light, this rock has some qualities by no means to be despised in hydraulic construction.

The supply of this rock is inexhaustible, and is usually to be found close to the dam. In one locality, near Salitran dam in Imus, the quarry was found some three hundred meters below the dam in the bottom of the same creek canyon. At the Dismo dam, in Sta Rosa, the rock has been excavated directly under the toe of the spillway, making an excellent water cushion, but being rather questionable construction, as can be seen at present by the numerous springs coming up thru the pit. The rock was taken out by picking

trenches vertically thru the beds and then splitting along them. Once a quarry is opened, surprising progress can be made -- one man quarrying as many as thirty stones in one day at the rate of about one centavo per stone in Spanish times.

In very few cases did any attempt seem to have been made to square the rock. Altho the faces of many of the dams are very well laid and sometimes complicated, the joints are generally over an inch wide, and in the interior absolutely no attempt at squaring was made. The most common size resorted to was about 20 x 20 x 60 cm. which was about a comfortable maximum lift for one man for a short distance and for two men for a long distance (80-120 lb.).

Altho much has been said to the effect that the method of making the mortar used by the Spaniards was a lost art, casual inspection can show nothing, either in composition or durability, to distinguish it from the ordinary lime mortar of modern times. The interior of the dams were laid up with a common variety of mortar, and the face with hydraulic mortar, the latter having usually lasted long after the rock has itself weathered. It would certainly be of value to investigate the wearing qualities of this mortar, as it adheres to the adobe much better than the modern cement mortar, and would be of course much cheaper. Cement mortar hardens too rapidly and completely to make a good bond with this soft rock.

From the available reports of the time and from observation it is evident that the location of an irrigation system was started at the dam, the site of the dam being chosen for a durable rock bed and walls and a narrow canyon. The foundations were rarely carried below the upper surface of the rock at the downstream toe of the structure, since they relied on great base width for re-

sistance against sliding; and this method allowed for the discharge of the stream to be disposed of more easily. In some cases a transverse trench or curtain wall was excavated and filled with masonry. Probably the two walls were carried up at the same elevation, the interior filling keeping pace with them. The latter seems in many cases to have consisted of cyclopean masonry.

There is no certainty, but it is probable from the scarcity of cheap flat timber during Spanish times, the great height necessary, and the unadaptability of bamboo for such height, that coffer dams proper were not used, the upstream face of the dam itself serving the purpose. In a very few cases by-passes are found around the sides of the dams; but whether these were meant as such or were due to floods during construction, it is impossible to say, as their upstream ends are usually nearly as high as the crests of the dams.

The stones were generally laid in horizontal courses, sometimes longitudinal to the dam and sometimes across, but never in any recognized header and stretcher bond. In a few cases of curved downstream profiles, the stones were laid perpendicularly to the face, but very seldom. This is natural, since the rock is about as strong one way as another and very easily cut after laying. The matter of stepping the face or not, seems to have been one of convenience -- in some cases done and some cases not. Often the downstream face was plastered, but like plastering has chipped off. The dam was generally capped with a mortar layer of varying thickness.

In shape there is an infinite variety -- too great for generalization. It is impossible to say much about the slope of the

upstream face, since in nearly all cases it has silted up to the crest, but in the few in which it can be seen and for which plans exist, it is commonly nearly vertical. The downstream face is sometimes sloped, anywhere between 1:4 and 1:1, sometimes curved in various modifications of the ogee with the difference that the upper curve nowhere presents the large radius of the true ogee. At the bottom of the dam an apron was often laid, sometimes flush with the level of the river and sometimes slightly above it. In a few cases the lower two thirds of the dam is of rectangular section or nearly so, and massive, above which a much thinner wall rises to crest level. The crest is of various widths in no way related to the height.

In general two spillway heights were allowed: first the entire crest of the dam proper; and second one or more smaller passages, generally narrower than two meters, so as to be easily stopped with brush or bamboo, and less than a meter deep. The dam face was generally cut in below these latter spills, so as to keep the water in its proper channel, and in some cases they were placed on one side of the dam proper, discharging thru a by-pass into the river below. By means of these spillways the water level could be varied somewhat, while the whole crest served as a discharge for floods. The Antigo dam, in San Francisco, was provided with holes in its crest, by sticking bamboos into which a considerable height of primitive flash board could be made.

The abutments of the dams were of different heights, evidently depending on the relative danger from cutting around. They were backed against the canyon side, and often ran upstream for a considerable distance. Sometimes they were quite ornamental in

character, being beautified by useless buttresses and pillars of masonry. In a few cases these abutments also serve as intake walls for the canals. In some instances, abutments are lacking, the general crest height being continued to the bank with no additional protection.

Table I, page 37, contains the principal dimensions of the most important dams. It would seem best not to burden the reader with unknown names, but in order to connect the dams with the descriptions elsewhere -- a few notable cases will be cited.

The Tres Cruces dam in the Sta Cruz estate is a final diversion and serves besides in somewhat of a storage capacity. It is about twenty meters high, and 220 meters long, and at the same time has probably the narrowest section of any Friar-Land dam. It is not over five meters wide on the crest, and its downstream face is on a 1:4 batter. It is built in three panels or spillways divided by downstream buttresses about 10 meters wide and extending two or three meters further downstream and one meter higher than the rest of the spillway. These can not possibly increase the strength, since the masonry will stand no tension, and they are too narrow at the base to act as true buttresses. The spillways take up about one fourth of the total crest length. The remainder is in reality a wall about two meters higher than the spillways. To the west it runs straight out in line with the dam and across an old by-pass or tributary to the river, while to the east it angles off upstream and forms the intake for the canal taking off from it. This work alone could easily be made to fill a book of description. It is a very impressive pile of masonry, and in excellent condition in spite of its narrow section. The pond above it, which has

silted up to within a few meters of the top, evidently adds to its security.

The Policena dam (Plate VII, page 64) on the Cañas River supplies the lands of San Francisco. It is 15 meters high, 35 meters wide on the crest between abutments, and is one of the most striking structures on the estates. Its downstream face is a close approach to an ogee, very graceful and well finished. Its abutments are about 6 meters above crest level, and are massive, the east one serving as an inlet wall to the water tunnel. The dam is not in bad condition, altho one portion of the toe is undermined and split off.

The Molino dam in Imus is the largest dam in the Friar Lands, and differs from the others in having been designedly a storage work. It is 15 meters high in the center, and about 300 meters long in its straight portion. The crest is of varying width, being offset in several places so as to be five meters wide at the center, while decreasing to three meters at the ends. This is the only evidence we have of a theoretical design in the work, for very evidently each section between offsets was designed for the head of water to which it would be subjected. The downstream face is straight, and battered at about 1:2, while the upstream face is nearly vertical. At the east end a buttressed retaining wall, at crest level, extends about 80 meters at right angles to the dam upstream to cut off a low spot in the bank. At the west the wall is also continued at crest level to form the intake of a canal and also of a side sluice or low level canal, both of which were provided with substantial portals and hand-hoist screw gates. The dam being for storage no abutments were provided. Near the

STATION 1



SECTION



SECTION 2

SECTION 3

SECTION 4

SECTION 5



SECTION 6
SECTION 7
SECTION 8

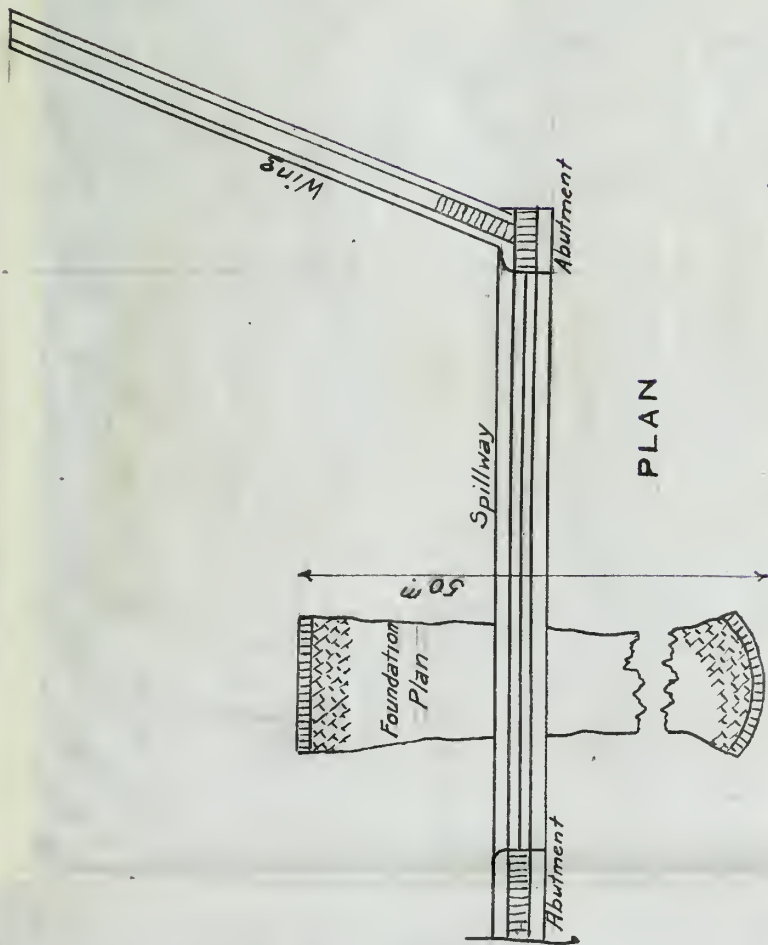
center is an under sluice, discharging under a maximum head of about 12 meters, and provided with a strong hand-screw hoist gate about $\frac{1}{2}$ meter square. The sluice is mortar lined, and extends completely thru the body of the dam, being of a sufficient size for inspection. This sluice has been successfully operated several times under American management. The dam as a whole is in excellent condition, altho it has been repaired but little.

Among other interesting structures in Cavite are the Ladrone dam (see Plate VIII, page 66), a very massive structure, Palautit (Plate IX, page 67), the highest dam on the estates, and Marcelo (Plate IX, page 67), probably the best preserved of all.

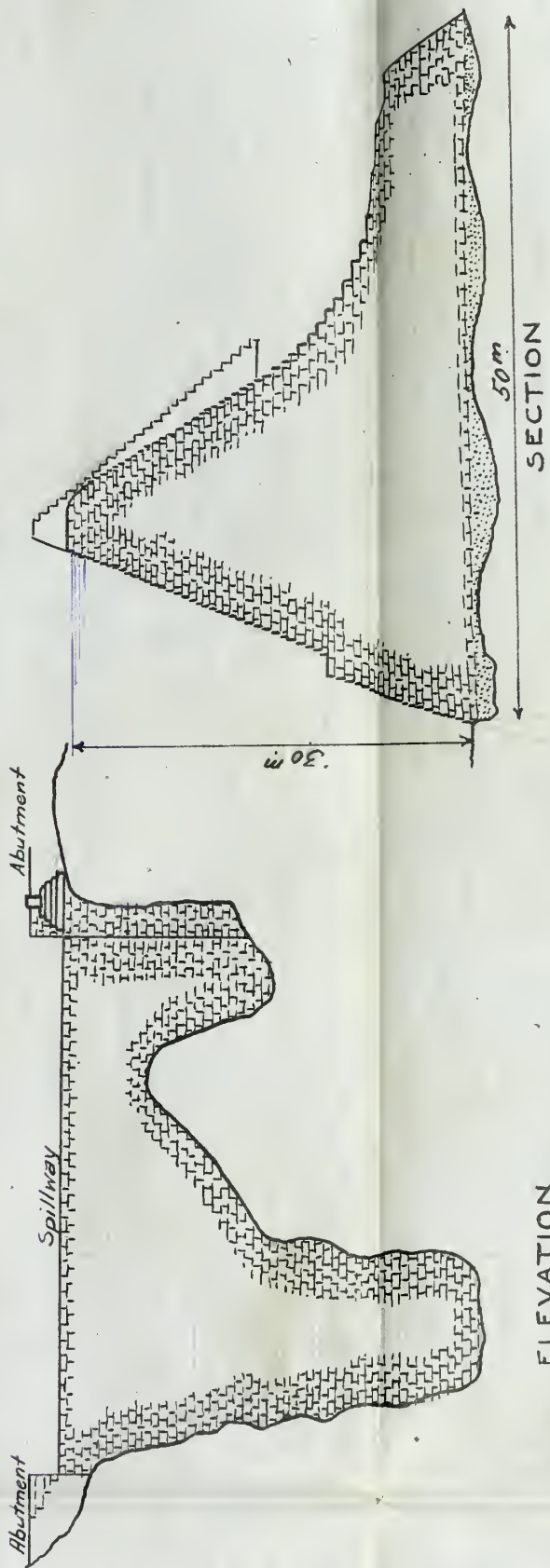
In Laguna, the old Dismo dam in Sta Rosa is of interest because its construction shows a noticeable absence of engineering scruples. In the first place it is built on the curve of a horseshoe bend of the river -- beautifully situated for cutting around. It consists of a spillway about thirty meters long and 0.75 meter wide in its main portion, which latter is pierced by one lower spillway. The dam is about 8 meters high, and is of a square section to within 3 meters of the top, from which height only a narrow wall rises to the crest. On the south a cut-off wall, about one meter higher than the dam, extends for about 100 meters upstream and across the neck of the horseshoe, spanning a side gully of the river, where a spillway is provided at crest level. Directly below this spillway is the quarry before mentioned. On the north side the wall, about one meter above spillway level, serves as an entrance to the canal, which is not provided with gates. The dam, contrary to usual procedure, is carried to the upper edge of the

Plan of the dam and
the foundation of the dam
from old Spanish drawings
to accompany the
S. C. Taylor

Scale 1:500

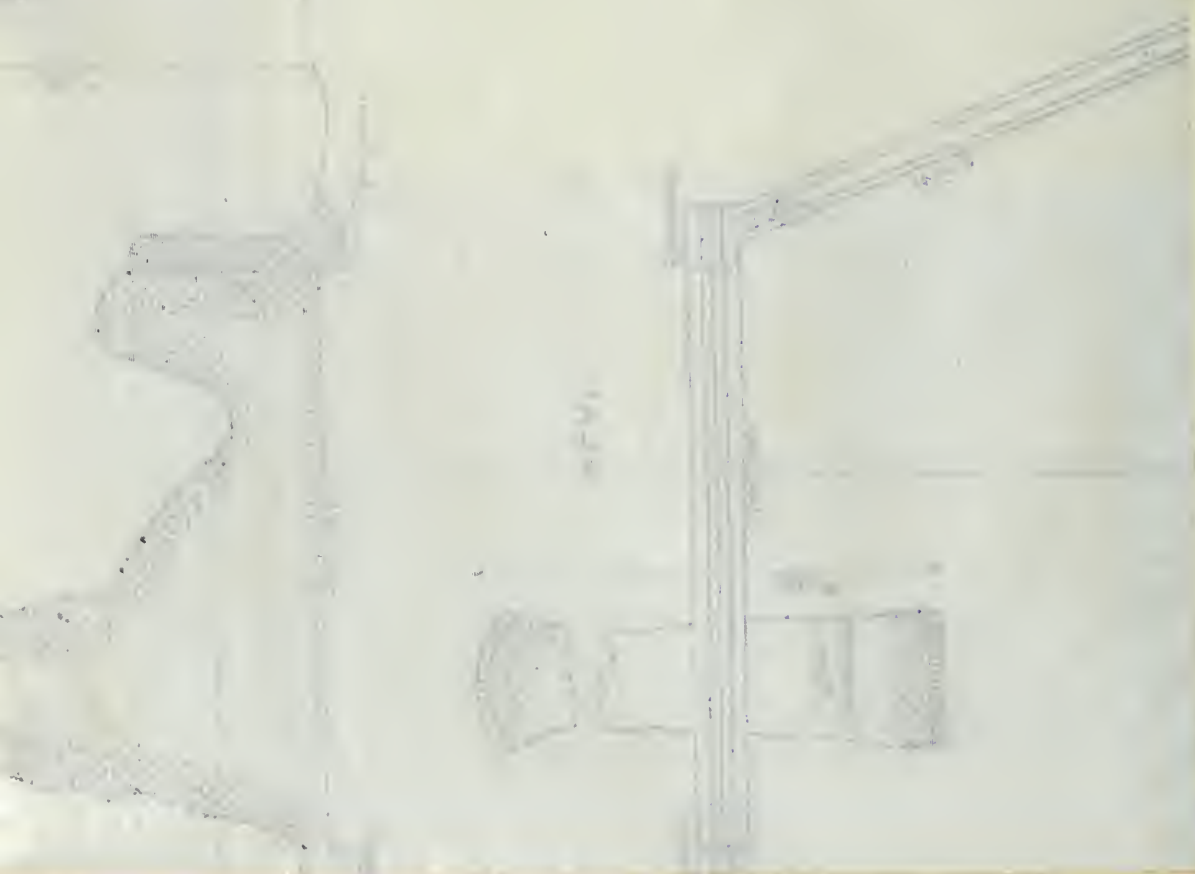


PLAN



ELEVATION

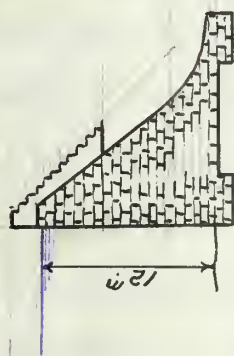
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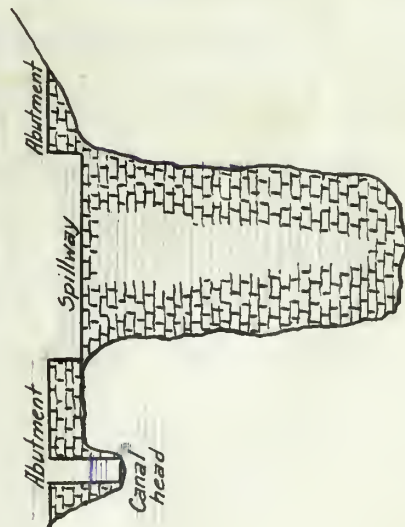


ELEVATION

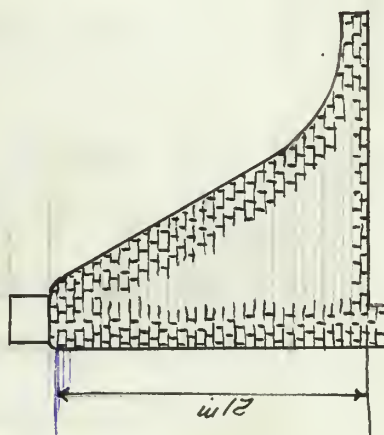
MARCELO DAM
PALAUT DAM



SECTION



ELEVATION



SECTION

SECTION 1



SECTION 2



SECTION 3

SECTION 4



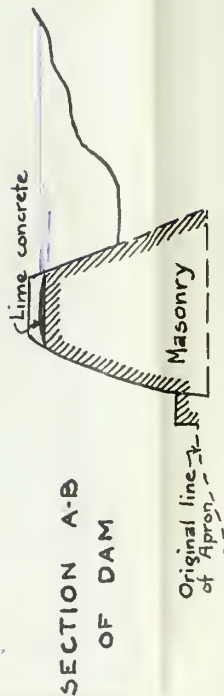
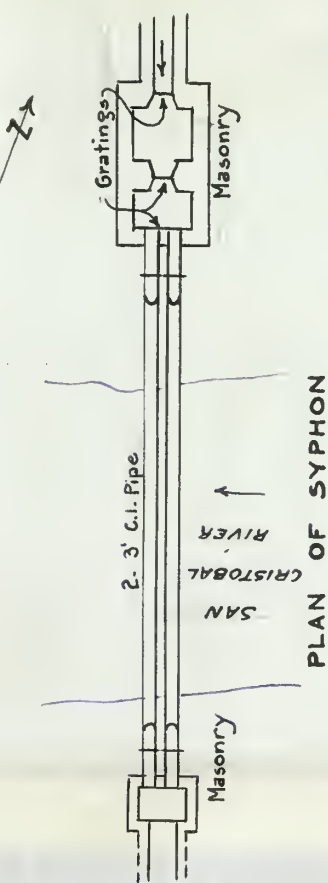
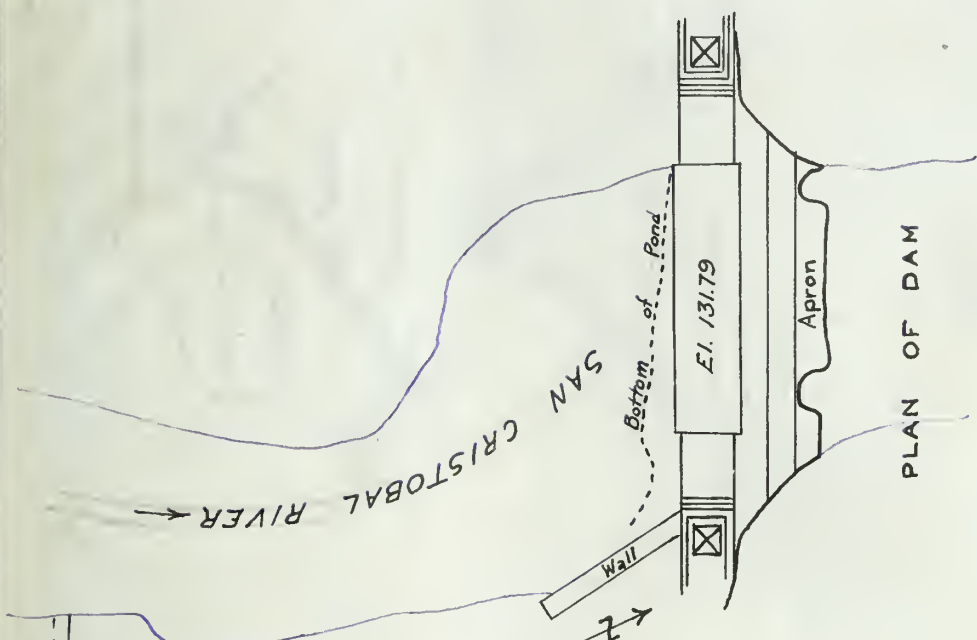
SECTION 5



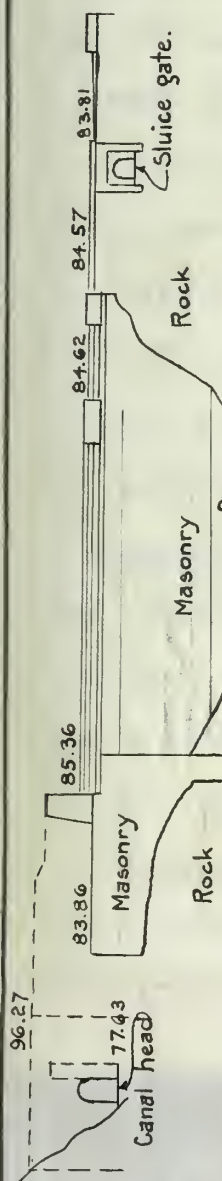
canyon, and presents unexcelled opportunities to the water for cutting around its sides and destroying it. However, altho it is in very poor condition generally, no special failure seems to be imminent.

The Campanã dam (see Plate X, page 69) in Calamba is of no special interest structurally, but is mentioned here because it was the last large dam to be built by the Friars, and is the most accurately and completely reported upon by them. Altho built as late as 1885, its masonry is not nearly so well preserved as that of the San Juan dam, which follows.

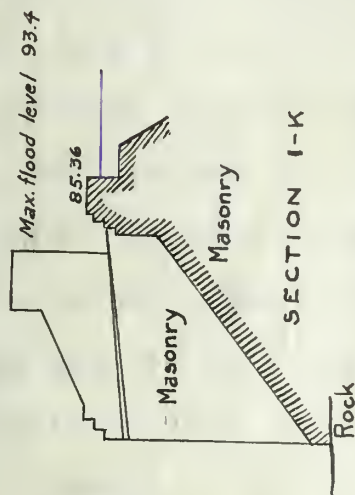
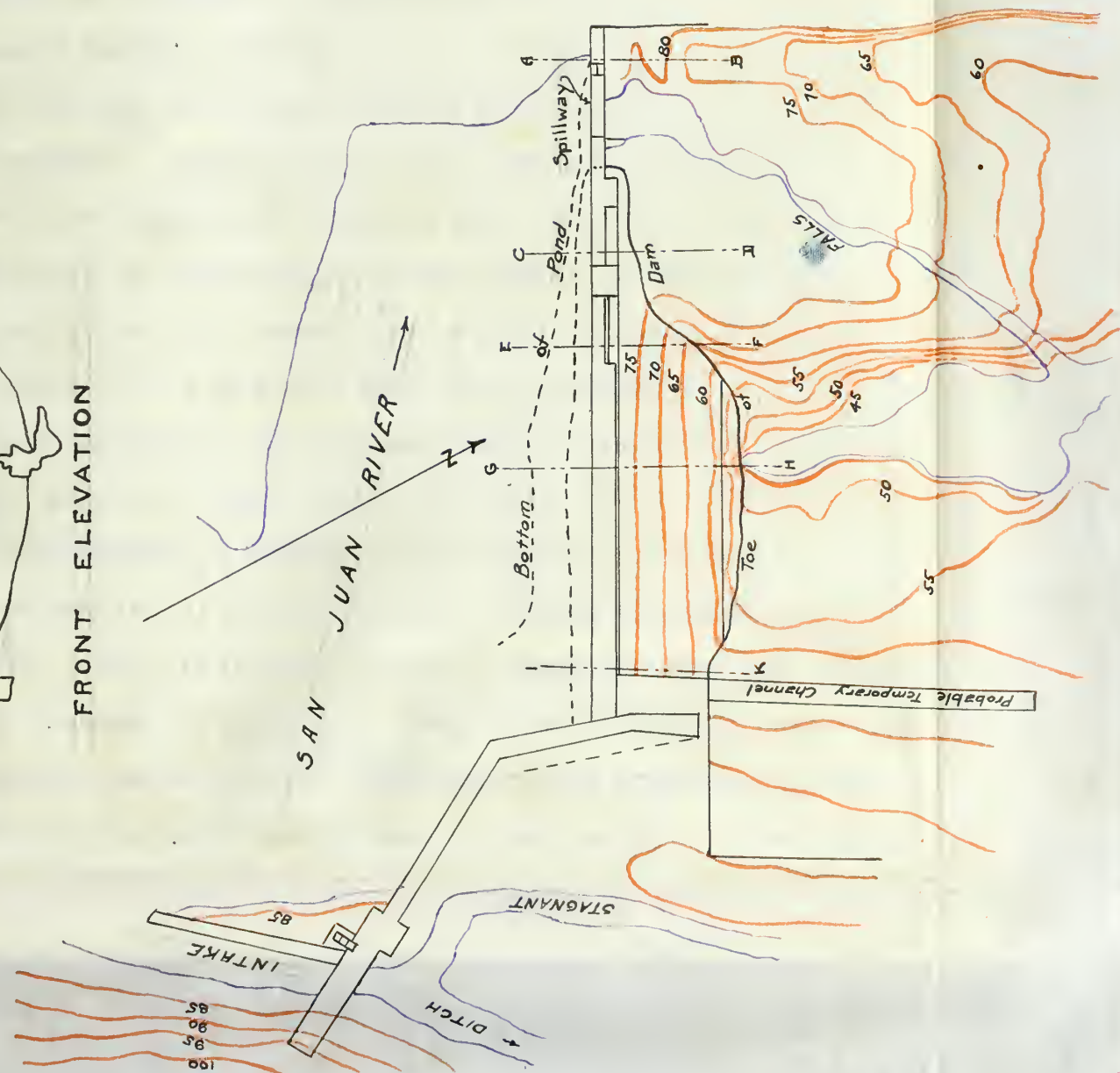
The San Juan dam, (see Plate XI, page 70), Calamba is one of the largest and most impressive in the Friar Lands, and heads one of the most interesting irrigation systems. It is 12 meters high in the center, 30 meters long in its spillway portion, and having one abutment 45 meters long on the south side of the river which serves as an entrance to the canal. The main wall of the dam has an upstream slope of about 1:4, and its downstream batter is in is in general 1:1, altho this is somewhat varying in different sections of the dam. The stability of this wall, in its center section, is expressed by factors of safety of 2.3 against sliding and 4.5 against overturning. The dam is provided with one spillway about three meters wide and 0.2 meter below the ordinary crest level of the dam, and the latter is offset in other places to form very shallow spills, the use of which the writer can not conjecture. One unique feature of this dam is the under-sluice, it being the only one of its kind within the writer's notice. It draws water two meters below crest level, is a little over a meter wide, and is arched at the top. Its upstream end is closed by boards and brac-



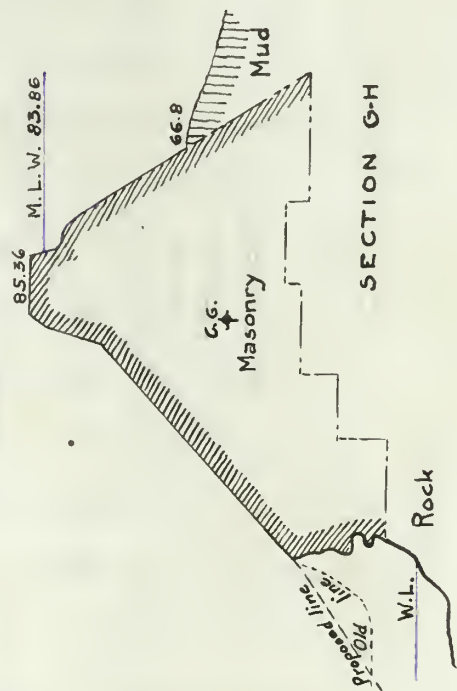




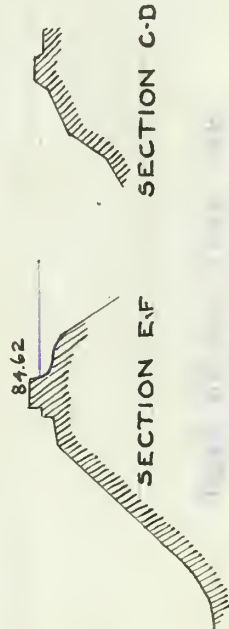
FRONT ELEVATION



SECTION I-K

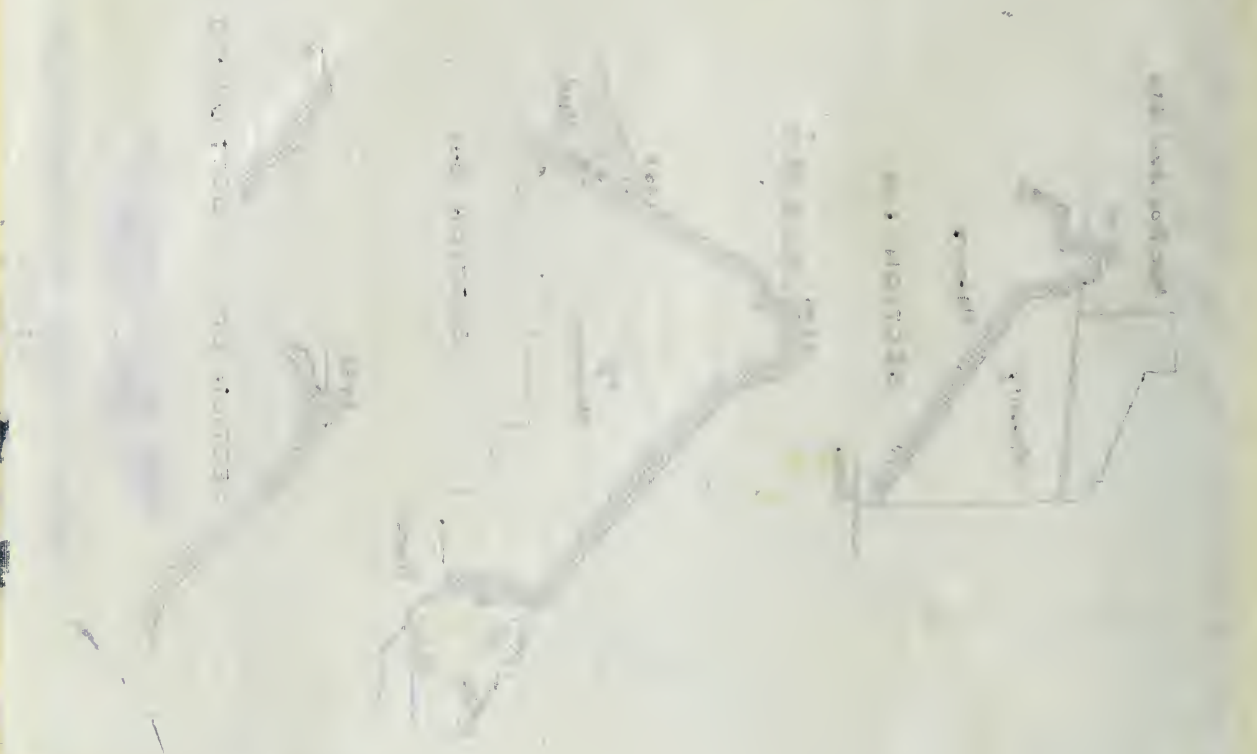
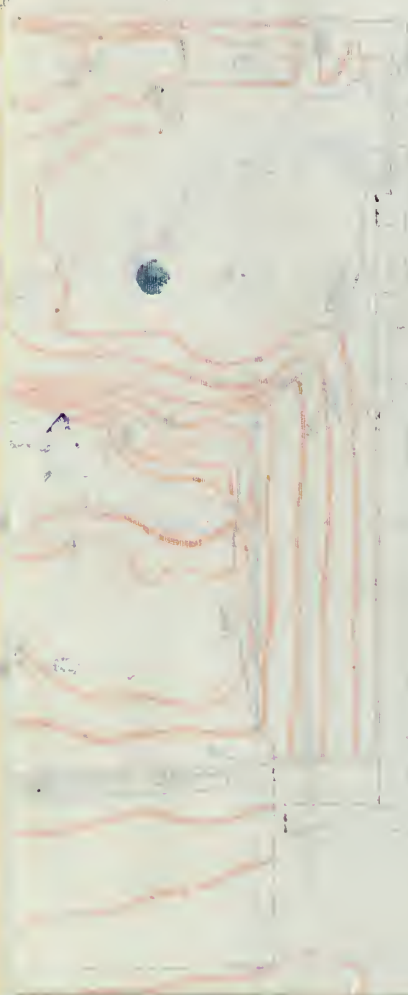


SECTION G-H



SECTION C-D

SECTION E-F



es, and the old procedure was to enter the sluice when flushing was required, cut the braces, and make escape before the head of water caused the door to fall. As the canal bed is only two meters below the crest of this dam, the sluice must have been effective in use. The dam ends without an abutment on the north side. The abutment on the south side is 3.5 meters higher than the spillway. The new tunnel takes off considerably above the dam. This structure was said to have been built by Asancha, the Spanish owner of the estate in 1760, and is in generally good condition.

TUNNELS. The main supplies for the systems on the Friar Lands were about equally drawn thru tunnels and canals. It has been mentioned that the principal desideratum in the choosing of the dam sites was to secure rock foundation and sides, and in most cases to secure enough headroom for the floods, which requires that the crest of the dam be placed a considerable distance below the top of the canyon. Since the soft but tenacious adobe offered a ready opportunity, tunneling became a favorite resort, and there are above fifty miles of tunnel of various lengths on the estates.

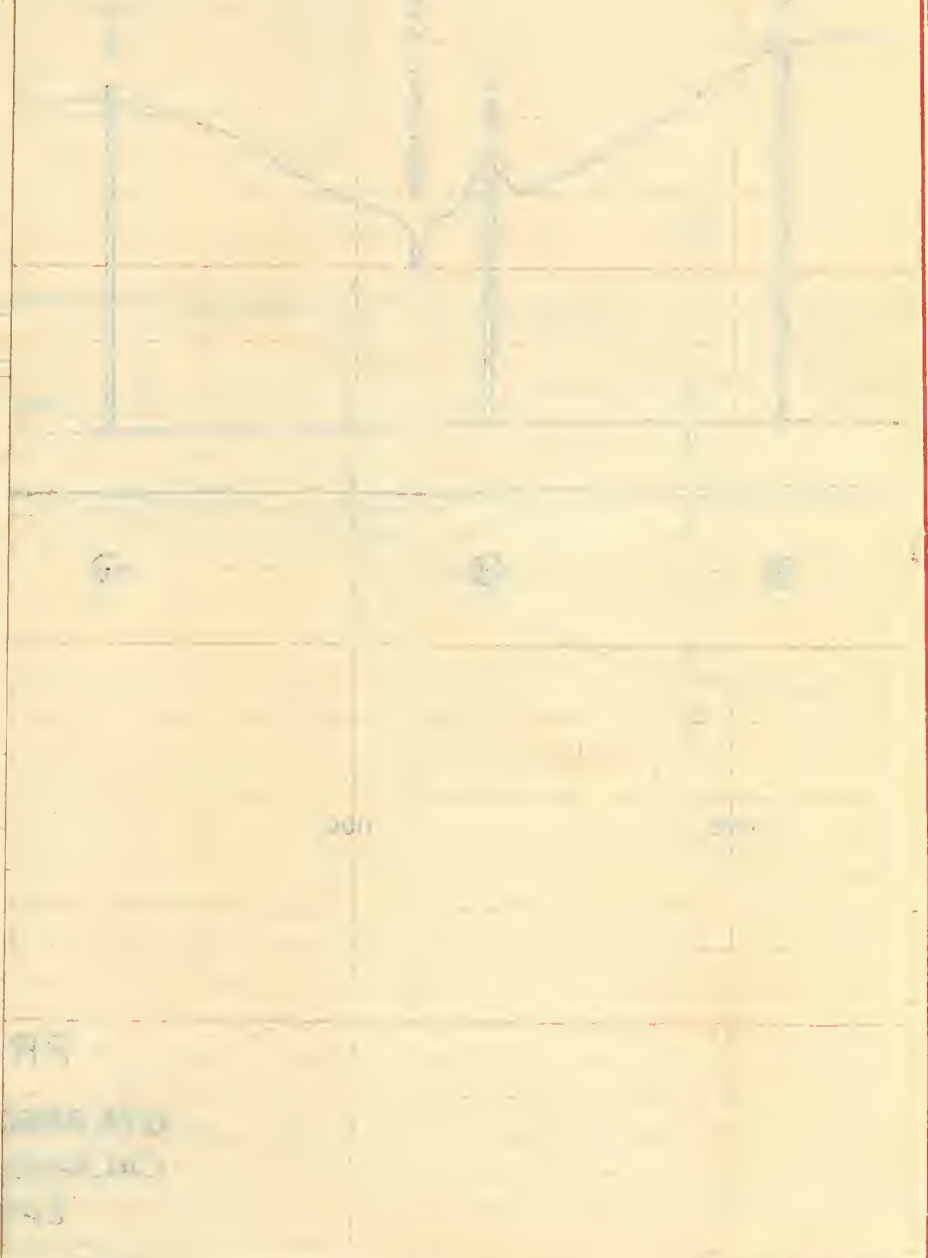
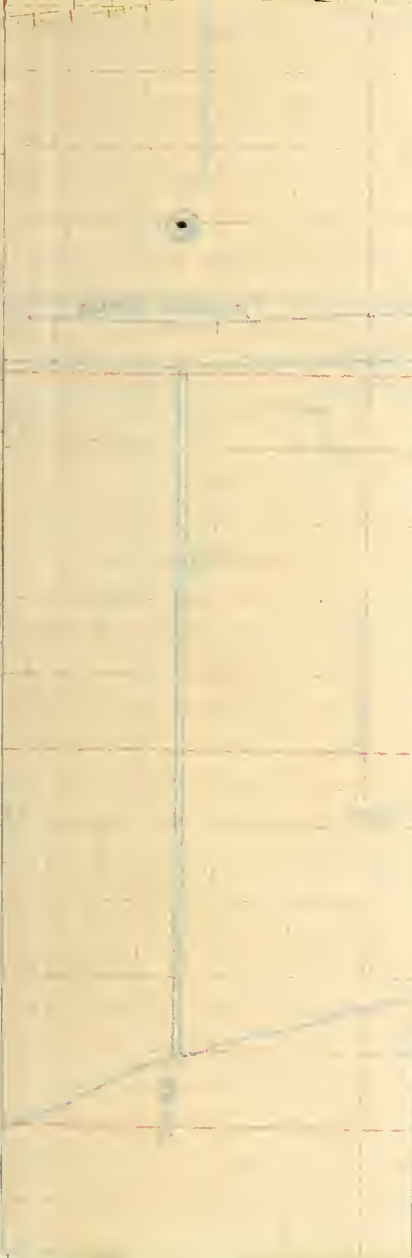
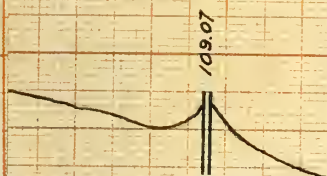
The section of the tunnels was almost the same in every case, about 1.2 meters to 1.5 meters wide, and 1.5 meters to 2.0 meters high, generally arched at the top and square otherwise. The intake was generally about 1.0 meter below the crest level of the dam, but where the most deplorable effect of the primitive methods of investigation is shown in the ridiculous and varying slopes given the tunnel grades. The first consideration seems to have been the dam location, the second the height of land to be irrigated, and often these considerations so clashed that hardly any grade was given the tunnel, resulting in an entirely insufficient supply. The writer

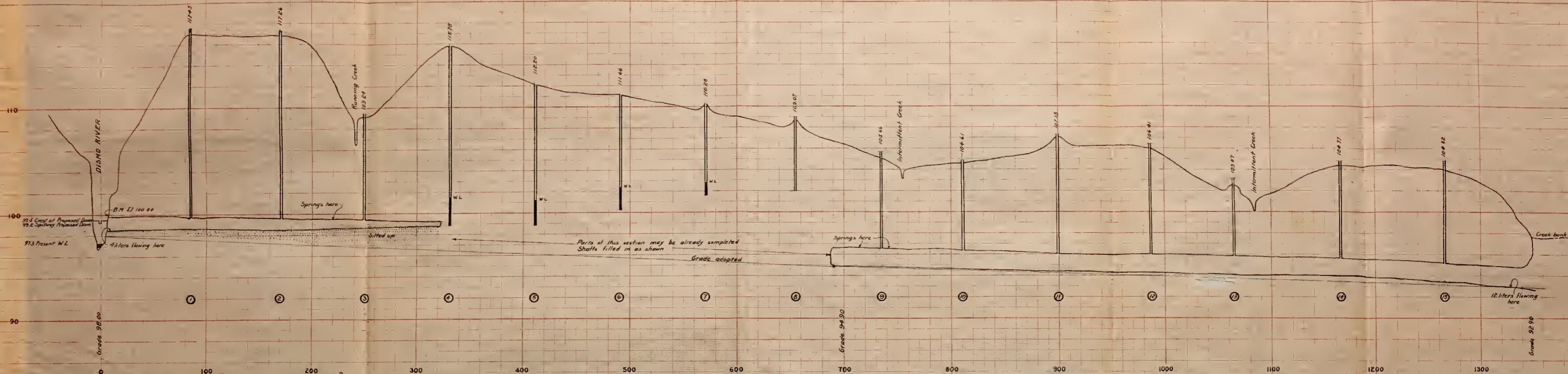
has seen water velocities ranging from almost nothing to two meters per second in such tunnels. The one at Calamba, laid out by the Friars, had no grade, while a neighboring one, in Sta Rosa, was laid out to a grade of 1:300.

All the excavating was done from shafts, which were almost invariably two meters square. These shafts were centered on a desired line, and the sinking of them to a desired grade was probably roughly checked by instrument. In some cases where the rock is poor the shafts are lined, and in a great many instances are arched with masonry leaving only a small square aperture to be covered with boards to prevent the collection of rubbish in the tunnel. No great skill was shown in the sinking of these shafts. They are seldom quite vertical, and often twist. On most tunnels the shafts occur at intervals of 50 to 100 meters, but are often closer together in shallow cases. On the Calamba tunnel the distance between the shafts varies for some reason, while on the Dismo tunnel, Sta Rosa, they are invariably 80 meters apart. See Plate XII, page 73.

The lines of the tunnels are usually not straight; in most cases they start more or less perpendicular to the river, and afterwards curve or angle down towards the land to be supplied. What the method of selection of these particular lines over absolutely straight ones was, the writer has never been able to determine; but he believes that the line was started from the stream and run in the general direction of the land to be supplied until some convenient creek or depression into which diversion could be made was approached, when the line was deflected to meet it.

Whatever may have been the method above ground, it is very evident that the line excavation was let by sections, and that in





PROFILES OF
STA ROSA TUNNEL (UPPER)
CALAMBA TUNNEL (LOWER)
LAGUNA PROVINCE

Reduced from copies in reports
by the writer.
Scale Vertical: 1" = 200'
Scale Horizontal: 1" = 2000'

PLATE 12
To accompany treatise by S.G. Cutler.

most cases no alignment was given. In cases the tunnel will start straight from a shaft, and afterwards deflect, missing that from the next shaft, and in others it never is on line and wanders around very aimlessly. The superiority of some tunnels over others in this respect suggests that some were supervised technically. The part of the Dismo tunnel completed by the Friars is with but two exceptions, aligned perfectly between shafts, while the Calamba tunnel has an offset between almost every shaft, showing where the two sections of tunnel failed to meet -- this offset being from one to five meters. It is rather peculiar that this is the case, as there seems to be little deflection of the compass needle in the tunnels, the writer having noticed that his own never varied by a great enough amount to have caused a noticeable error in alignment between shafts; but perhaps the work was done like that of a Manila Spaniard who ran a compass line along the top of the steel water supply main, and in these tunnels iron pumps and pipes were convenient.

In some cases the tunneling was very well done, the shape, size and alignment being regular. No attempt was ever made at continuous lining even in soft spots, altho in a few cases, probably where cave-ins occurred during construction or where a faulty line was to be closed up, a wall of adobe masonry was put up. However but very little deterioration is evident, even in the oldest ones.

The grade is usually so smoothly made as to be to the unaided eye correct. It is quite likely that the grade was made level between shafts at first, and afterwards cut down. In the Dismo tunnel for instance, from the entrance from shaft 4, where

the Spaniards stopped work at the upper end, the bottom of the tunnel proved to be absolutely level; but at the lower end, for a distance of 675 meters the tunnel was on a perfectly even grade of about 1:300. In the Calamba tunnel before mentioned, it may have been the intention to cut down the grade, as was subsequently done by the Americans, to 1:1000.

The lower end of the tunnel usually discharges into a creek or very deep cut, which carries the water down to the irrigated area. In places these cuts are open, in places arched, and in places both arched and filled, so that it may be guessed that it was not the intention of the builders to leave them open indefinitely. In general the Friars seem to have tunneled rather than trenched where the cut was over five meters, altho this is not invariable either way.

In several cases the old tools of the workmen have been found in abandoned headings, and consist of picks, wedges and drills. Gunpowder was used for blasting, and succeeded better than dynamite in that class of rock. Excavated material was raised thru the shafts by hand. Hand pumps were often used in closed shafts, and one steam pump cylinder has been found. It was made of six wooden segments bound with three iron hoops, and was about 8" x 18" in size. The valves and plunger were also of wood and leather, while iron rods and pipes were used for lift rod and casing.

The only tunnel which exceeds the Calamba and Sta Rosa tunnels in length and importance is the Bancod, at the head of irrigation in San Francisco de Malabon, Cavite. It is of the ordinary section nearly five miles long, broken by three aqueducts over drainage. A great amount of work was necessary to condition this after American occupation, and it is at present in need of repair. This

tunnel has a very erratic line and grade.

MAIN CANALS. Of course a few of the systems are so situated that the dam can divert water thru a comparatively shallow cut, and many of the tunnels give way to canals a short distance from the dams.

It is difficult to say to what exact size and section the canals were dug in the beginning, time and use has so changed both, and at the present time those which have not since been repaired present the appearance of overgrown creeks.. Perhaps the best example of a large open ditch perfectly familiar to the writer is the main canal of the South San Juan system, Calamba. It is about a kilometer long on a grade of about 1:1000, and carries 500-1000 sec. lrs. Altho it has been repaired, it is quite evident that originally it was about 3 meters wide and 1.5 meters deep its banks being sloped at about 1:1 in earth.

It has been previously mentioned that the usual plan in rock was to dig canals with vertical banks -- probably with the intention of making closed cuts of them later. How many of the so called tunnels were originally arched cuts is unknown, since most of the smaller ones have never been entered, but the writer has inspected one such in Calamba, about 100 meters long. Even if unarched the tunnels have survived remarkably well, very little caving in having occurred. This is more remarkable, since in every case the slope is increased in rock and the cut becomes a veritable sluice, velocities of three and four meters per second having been observed in such places. One of the most remarkable cuts of this kind is below the Calamba tunnel -- one meter wide, and four to six meters deep. The writer ran the line of this cut, and observed

the slight effect of weathering at the bottom.

Owing to the smaller divisions into which the main diversion was divided, the frequent use of watercourses in serving the purpose of main canals, and the high velocities obtainable in the rock cuts, what would be considered as large canals in the United States are unknown, and lining is as unheard of in the canals as in the tunnels, much simplifying the problem from an engineering point of view.

The slope most generally found in earth cuts is 1:1000, or a little greater in very small ditches. Practice shows that in the ordinary regime of the average ditch of the size referred to, this produces a velocity of about 0.6 meter per second, which would hardly have any effect on the tough clay generally met with in their bottoms. In a few cases the slope is much less, with no apparent reason, which is another strong evidence in the writer's opinion that the Friars used rather primitive methods of calculation or that their desire to irrigate some particularly choice high land blinded them to the obvious drawback.

Berming was not done, the side slopes being continuous; and this method is justified by the fact that the top of the bank serves as a path for men and animals who cause enough trouble as it is, but would undoubtedly use the berm as a drinking and bathing place convenient to the water surface and soon cause the bank to cave in.

CANAL STRUCTURES. The headworks of the canal were as a general thing in one of the abutments of the dam, for obvious reasons. These headworks in the case of a tunnel generally took the form of a portal provided with slots for the insertion of a weir of varying height. With the exception of the headgate at Molino dam

before referred to, the writer has never seen a tunnel controlled by a regular hoist gate. In one other location in Cavite the tunnel was evidently provided with a hoist gate, as a very creditable little gate house is still standing above the place, but the gate was evidently removed or stolen. The gates in use in an open canal were similar, the water leaving the river thru a masonry chute, at the beginning of which were slots for the reception of logs or bamboos. Almost all these entrances are now provided with the standard gate of the Irrigation Division, Bureau of Public Works.

Among the more numerous canal structures of interest are the aqueducts, of which the most famous are found on the line of the Bancod tunnel. The first, a masonry arch, is the longest. It has a clear span of about 15 meters and is about 30 meters high. Along the crest of this arch the water runs in a trough of masonry. This aqueduct is provided with a wasteway discharging into the gully below, and at present controllable by means of a standard gate. The aqueduct next further down, known as "tres tubos" is composed of three lines of iron pipe about 18" in diameter with bolted joints supported on iron girders in a span of about 15 meters. These girders rest on masonry abutments, but are poorly set up. Two of them bolted end to end on flanges, are held together only by a few bolts which are well rusted already. Numerous small aqueducts of masonry are found all over the estates.

Another interesting structure, the only one of its kind on the estates, is the inverted pipe syphon on the Campaña system of Calamba. This is composed of two lines of 36" iron pipe with leaded and caulked joints. The syphon is provided with masonry settling basins at both ends. Its ends are at approximately the

same level, while the pipe is full at the intake it is only about half full at the discharge, and the velocity is exceedingly low in the bottom of the pipes. This was built later than 1890, but it became completely silted up by the time of the American occupation. It is evidently too large and is improperly designed, but is an imposing structure nevertheless. (See plan)

The insertion of canal falls was probably a development from the old bamboo weirs. Traveling along the Cavite roads one passes scores of these. They are generally mere bulkheads with upstream wings, their notches being provided with slots into which wooden or bamboo baulks can be inserted to raise the water to the lands. They are in a variety of shapes however ranging from the most simple to an intermediate between a fall and a dam provided with abutments, ogee, and apron. Indeed in Sta Rosa the writer observed twenty different falls, each of a different design.

The writer has seldom seen these falls in such a location as to control the flow of the canal to any extent, and of course where the drop can be increased or diminished as the landowners desire, the study of the effect of the falls is rather complicated. In general however they were placed about a kilometer apart on main supply channels, a sufficient distance to allow plenty of fall, and not too great for the land to be irrigated from one point.

In several places structures were inserted at the branching of main canals, each provided with the necessary slots, but lateral heads proper were not thought of; although a simple outlet in earth in which a temporary bamboo dam served to cut off the supply was the regular practice.

DISTRIBUTARIES. The laterals and sublaterals were small-

er editions of the canals, being almost always 1.0 meter wide on the bottom, with bermless 1:1 side slopes and banks one meter above the bottom of the canal when the latter was entirely or partially in fill. In these small ditches no attention whatever was paid to slope, beyond running them approximately perpendicular to the contours. Wherever there was opportunity or occasion a few stakes would be driven in the ditch, and the addition of cogon grass and mud would complete a field -- ditch diversion. By oft repeated additions and alterations these ditches have become exceedingly complicated, as can be seen in the various distribution maps presented, which remind one strongly of the analogy to the circulation system of the human body.

The universal method of field irrigation in the Philippines is by means of square or quadrilateral fields or "paddies", separated by dykes, matted and over grown with cogon and rice grass. In hilly land these dykes follow contour lines approximately; and on uniform slopes they are laid out on a rectangular system. Generally speaking the paddies are about 30 meters square, that being about the size to form a mean between a sufficient depth of water at the high end and a not inconvenient height of dyke at the low end. The dykes in ordinary cases are from 30 to 60 cm. in height, and not only serve the purpose mentioned above but form convenient paths, and two of them, parallel and about one meter apart, often form a field ditch. Their use as regulators of supply will be fully discussed in the next article.

METHODS OF DISTRIBUTION.

It is in the schemes of distribution that we find the most

distinctive features of Friar Lands irrigation -- these features, as before mentioned, being caused by the direct incorporation of native methods into the larger units necessary for an economic supply. The general methods of primary diversion have already been pretty fully described. Briefly the water is turned from a river into a tunnel or canal which carries it into some small subdrainage course parallel with the river but sometimes directly to the irrigated land. The general principles of secondary diversion have also been mentioned. There remains to describe the method of applying the water to the land, and of utilizing the drainage.

The general method of applying the water consists in first diverting it from the main canal or secondary dam into the small swampy creeks which are common in the vicinity, and afterwards raising it where needed to the surface by means of small bamboo dams. The latter are unique in a way, and are very convenient. The bamboo dam constructed by placing a long pole across the water course and staking it firmly to either bank, then driving similar poles in the bottom so that their upper ends rest against the horizontal one to which they are bound firmly with rattan. These latter form a continuous wall, except for the space of a meter or so in the middle, which forms a sluice, and are stopped as high as required by short horizontal sticks which span the opening. Such a weir, when caulked with grass and mud, is quite water tight, can be completely opened or closed in five minutes, and lasts several years with trifling repairs.

The usual custom is to raise the water to the required level directly for the first and highest paddy adjoining the water-course. Sometimes however a small ditch will take off instead,

running at a low level parallel and near the watercourse and receiving the drainage from higher fields to be re-diverted when it reached a high enough level. The latter is of course employed when the ground slope is rapid.

The writer believes that the use of small water courses thus was developed and that they were originally canals which on account of their heavy slopes and the failure to take precautions against floods were worn into their present condition, necessitating larger and higher weirs. This view is supported by the fact that they are always on ridge ground.

FIELD DYKES AND CHECKS. As has already been noted, rice paddies are laid out in straight-sided, generally rectangular areas of from 0.1 to 0.3 ht. in such a way as to obtain a level sheet of the required depth over the entire field. With but a few exceptions irrigation starts near the creeks, or laterals as they will subsequently be called for convenience. In a great many cases the field distribution is effected absolutely without ditches, the water simply flowing from field to field and being regulated as closely as necessary by cutting small spills in the dykes between paddies which can be stopped at will. Where it has been found that the flow off from the upper fields has become insufficient, another weir is inserted in the lateral and the same process is repeated. The commonness of this method is of course due to the rapid drop of the land, the water soon being able on that account to reach fields at some distance from the lateral. In a few localities where the slope is less well developed sublateral systems appear, the water being turned into the ditches from the laterals in the usual manner and

then run down the land until it reaches the ground level. The fields are then flooded by inserting a bamboo stop in the ditch and opening a small space in the bordering paddy dyke thru which the water enters it. When one field is sufficiently flooded the stop is moved to another place.

In a very few cases has the writer found Spanish ditches entirely in embankment, the danger of that method being great in a country subject to torrential rains. In no case has he found it done for purposes of distribution, the canal in cut with sufficient embankment to allow for temporary stops being the rule. In no case has he seen distribution ditches taking out of the canals in the few cases where nature necessitates a fill.

The material for embankment where excess was necessary was taken from the immediate vicinity of the canal. Where paddies border the canals, these depressions soon become filled by plowing and puddling so as to be no drawback.

It often becomes necessary in level country to span one ditch in order to bring water across it at a higher level, and this was frequently done by the small masonry culverts of the Spaniards, or in native imitation by means of plastered bamboo or sheet-roofing chutes.

DRAINAGE. This forms one of the most important factors in Friar Land distribution, and really accounts for the lack of economy in the use of water. It has been remarked by engineers that most of the canals "begin nowhere, and end nowhere". The great majority of the land in question has a very definite artificial hardpan along which almost all of the excess water seeps and eventually finds its way back to its original bed. Thus it can be used again and again,

for a long ways down the slope. One method for regaining the water is well illustrated in the Cavite systems -- long, narrow ones. When one visits a river just below the dam one finds hardly any water, yet two or three kilometers down another dam will be inserted which will make a respectable diversion. Some of the water enters directly, flowing off thru the paddies; but the numerous "springs" in the river beds show that most of it is seepage.

In Sta Rosa there occur several cross ditches which starting nowhere in particular still give rise to rather extensive lateral systems. They were probably dug with a view to receiving and re-distributing surface drainage, but do nevertheless collect a good deal of their supply from subdrainage.

It has been the rule to conclude that because a great deal of water enters the fields water is used uneconomically; but since his attention was first called to it, the writer has taken many opportunities to observe it and as a result has found that altho the first applications are wasteful in most systems the total amount used on a large tract approaches closely the theoretical duty, and conversely that a lower duty figure than the average obtained on the Estates is not practical.

ADJUSTMENT OF SUPPLY TO DEMAND. This is probably the least studied or understood irrigation question in the Philippines. It is known that landowners have methods of regulating supply between them, or more commonly on different parcels of the land owned by an individual.

The most embarrassing time is when the fields are receiving their first flooding. This requires a large amount of water, perhaps 3 sec. hr. flowing for an hour to flood the average paddy.

The general method is to cut the spill in the first paddy dyke at the required elevation, so that when the current fills the first paddy the water will overflow into the second, and so on. This works very well on the land of one man, but where another's land adjoins there seems to be some sentiment against his giving water to his neighbor in the same way. This causes a good deal of complication and extra diversions and field ditches are often necessary. Judging from the way in which it busies the present "celladores", the matter must have given the Friars a good deal of trouble. After the first flooding the lateral weir is lowered so that the water just keeps its level in the paddy, the outlet spills being gradually built up as desired. This is sometimes varied where the supply is thru a sublateral by admitting water on different days to different fields just enough at a time to maintain the desired depth.

Complete drainage is of course a simple matter where the ditches are in cut, all checks being taken out of the latter, and the dykes cut thru to field level, when the water at once drains off. In some cases a much wider adjustment is necessary where the dry season supply is not sufficient for the land. Then an agreement must be made by which some lands receive the water one year and others the next year. This is practiced in the majority of the estates, being noticed by the writer in San Francisco, Imus, and Sta Rosa, and he was informed that the system was instituted by the Friars after many bitter disputes among the tenants.

DESCRIPTION OF IRRIGATION SYSTEMS.

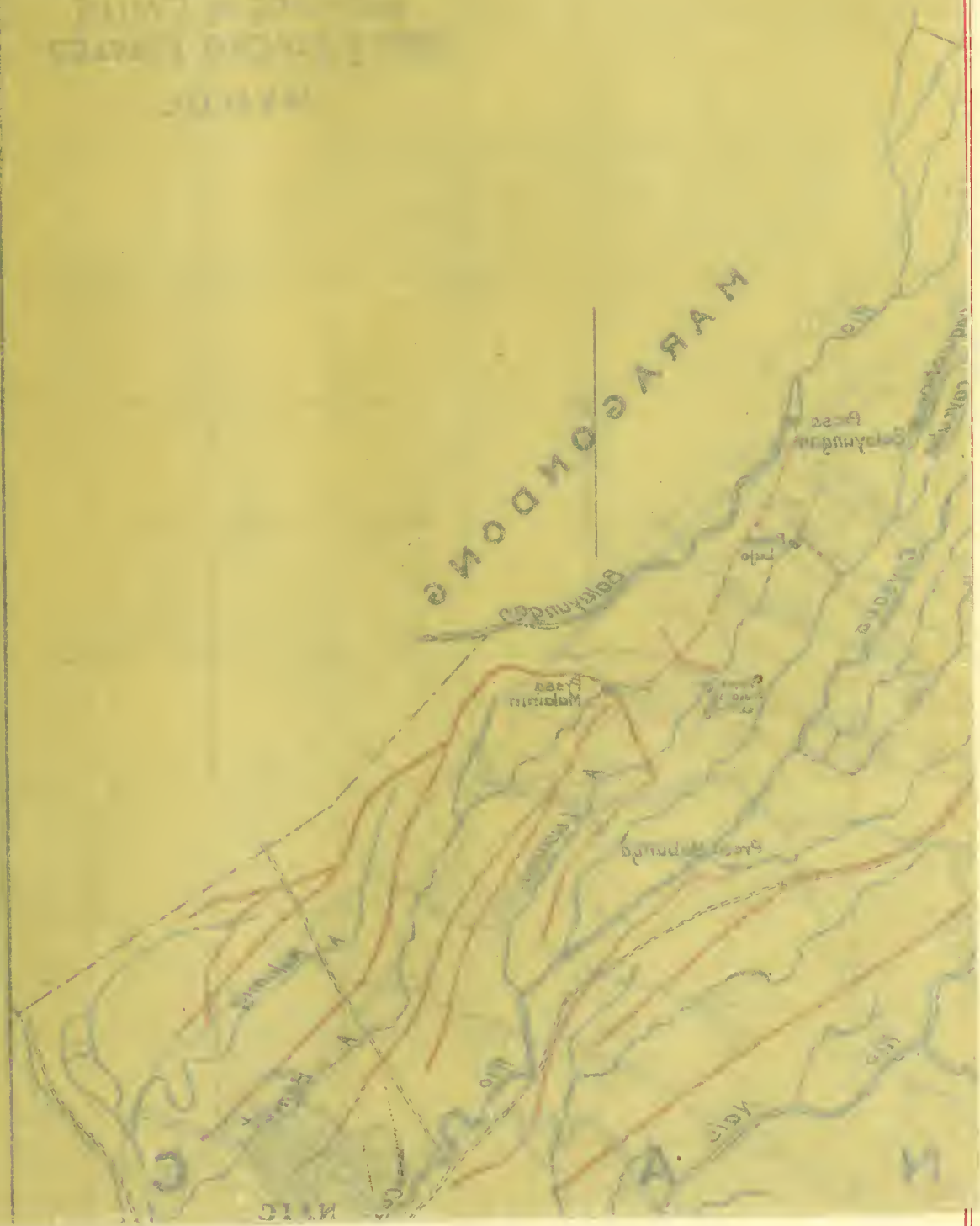
The reader has probably waited with a good deal of patience for the usual list of names and locations considered indispensable

in an engineering paper. The reason that the writer has not introduced them sooner and that he will at present give them comparatively little space is that they not only confuse the person not familiar with Spanish and Tagalog nomenclature, but are to a large degree inessential to his subject, the object of which is more to give an idea of the nature of this work than to actually describe it in detail. However, in order to give a tangible appearance to the paper and to connect some of the larger works with their proper locations in the reader's mind, he will now briefly outline the systems severally.

NAIC. The Naic system (Plate XIII, page 87) is a comparatively simple one, employing only two main diversions. One heads in the Balayungan River at a large dam of the same name, and after passing thru a tunnel is reinforced by another diversion from the Culong-Culong dam. These diversions irrigate land west of Naic. The other heads at the Calumpang dam and irrigates south-east of Naic, but is insufficient for the area attempted. The small development of this system is probably due to the land having been acquired rather late.

STA CRUZ. The Sta Cruz systems are well developed, tho small. The estate is cut up by numerous very short Bay drainage streams, while the only large rivers are near its boundaries. Three of its systems required special consideration. One takes water from the Alolu River near the Naic estate and carries it by two diversions to the Maralin River, where the massive Tres Cruces dam serves somewhat in a storage capacity and also makes the final diversion. A fairly large supply is obtained by storing and consolidating four streams in the center of the estate. This is one of

Plate XIII.



the striking examples of the means resorted to for a small amount of irrigation, since the dams Legidero, Postema, and Pajo are all of fair size.. The third supply, is from the upper dam, Molino Sta Cruz, in the Cañas River, which dam will later be mentioned as establishing the Dominicans right to the water in that river. That the Friars obtained storage on this estate by plan and not chance is seen by their departure from their usual methods of choosing dam sites -- see Plate XIII, page 87.

SAN FRANCISCO DE MALABON. It will be noted on the map (Plate XIV , page 89) that this estate possesses about the entire water right to the Cañas River, but that the bifurcation of the latter occurs so low that it is impossible to irrigate the greatest amount of land by means of a diversion below the point of branching. Another factor which complicated the problem was that the Dominicans the proprietors of the Sta Cruz estate to the west, had already located the Molino Sta Cruz dam on the same river, a diversion which furnished most of their supply. It therefore became necessary for the Augustinians to plan to collect all the water possible from the branches of the Cañas passing thru their territory without interfering with the supply of the neighboring estate. It is possible that in preliminary explorations the River Bancod had been found and a water right established, and also that a strip of land along which to make a diversion thru the Municipality of Indang had been obtained. This river has a moderate mountain drainage area, and is the main branch of the Naic River, the principal stream in the estate of the same name owned by the Dominicans; and it is probable that some agreement was made with the latter by which its supply was exchanged for that of the branches of the Cañas appropriated by the

latter in Augustin territory. At any rate it is significant that none of the irrigation of the Naic estate originates in that particular branch of the river.

The Bancod was accordingly dammed, and a tunnel run crossing the several branches of the Cañas on aqueducts. Four such crossings were required to pass all the streams appropriated further down before the water could be discharged into the Panisayan, the first tributary of the Cañas to join the main stream below the Dominican~~s~~ dam. This river was also utilized for supply, having an extensive drainage area, and both its own water and that of the Bancod were rediverted lower down into another tunnel by means of the lofty Palauit dam. This tunnel carried the supply to the Matangilan River down which it was allowed to run to a point where diversion to the land became practical. From the Buloc dam part of the water went to supply the lands in the vicinity of Buenavista, while part was carried across country further to reinforce the Ualan River.

One of the diversions from the River Ualan was in the center of the estate by means of the Ladrone dam; and it is evident that this diversion did not prove sufficient for the land to which the system was eventually extended, for at a later period the Marcelo dam was built on the main stream, Ilanilan to divert water into a small arroyo, which was rediverted at several points to reinforce the former supply. The San Francisco system is as old as that of Imus, and if the Marcelo dam had been the original diversion it is doubtful if the Augustinians would have permitted the Recoletos of Imus to make such a large diversion above them as the San Agustin dam accomplishes; and hence it is reasonably certain without consid-

ering the present excellent condition of the Marcelo dam that it is a late diversion. The supply thus reinforced evidently became too small again, for it became necessary to augment the supply of the Ualan River by the before mentioned diversion from the Buloc dam. It is possible that the Bancod supply was not utilized until this last call was made.

Near the town of San Francisco is the Antigo dam, said to be the oldest in the Friar Lands. It originally irrigated the land in the vicinity of the town, but was evidently unable to furnish enough water after the building of the Ladrone dam above it in the same stream (Ualan River). Its supply was therefore reinforced by the Policena dam, built below the diversion of the Dominicans in the Cañas River.

It is exceedingly difficult to trace the true history of these systems, since the older works were built before the time of the Friars, and many of the newer ones before any records were kept. However, by the best means available of judging the age of the works it seems likely that the operations were in the following order: (1) Diversion from Ualan River by Antigo to lands around San Francisco; (2) diversion from Matangilan River by Buloc to lands around Buena-vista; (3) diversion from Ualan River by Ladrone to the eastern side of the estate; (4) on account of the above shortage of supply to Antigo and its reinforcement by Policena on the Cañas River; (5) reinforcement to support Buloc from Marcelo in the Ilanilan River; (6) further reinforcement of the same system by the Bancod works which turn an additional supply into the Matangilan River.

IMUS. The Imus system of irrigation (see Plate XV , page 92) is the most complete of any. It comprises three main di-

MAP OF
IMUS ESTATE.
PROVINCE OF CAVITE
SHOWING IRRIGATION SYSTEMS
From filed copy 7034 B.P.W.
Scale 1:50000

PLATE 12
to accompany the report of the
Cavite Irrigation Survey



PLATE 15
To accompany treatise by S. G. Cutler



versions. The first of these for boldness of conception almost equals the Bancod works. It was necessary to cross several deep tributaries of the Ilanilan River to reach the irrigable land about Perezdasmariñas, but the result was accomplished without crossing other streams whose water was already appropriated. The San Agustin dam is at the head of the diversion, the supply being reinforced in re-diversion by the small dams Nancan, Jassan, and finally Casundit. In spite of this elaborate system it apparently became necessary later to make another diversion from the Ilanilan below the Marcelo dam of the Agustinians.

The second system is a simple one, heading at the Trapiche dam on the Imus River and irrigating the central part of the estate down to the town.

The third and largest supply is derived from the Malaquín-ilog River far up in the hills. The Embarcadero dam diverts its supply into a small stream, the San Cristobal, which carries it to the dam of the same name. This dam diverts part of the water on to the lands around Paliparan, while the rest continues down its bed to the Baluctot dam. The drainage from these lands which finds its way to the Guaya (Buya) River is raised again by the dam of the same name, and twice more below by similar processes by the Bocal and Bucod dams.

In spite of this elaborate system, it seems that there was still a quantity of water flowing off, for the owners then proceeded to erect the most impressive structure of all, the Deposito Molino dam, which stored the drainage waters descending the Rivers Alapan and Quirapdap and turned them onto the lands on either side. The diversion was by means of one high level line to the west rein-

forced by a low level line, and one low level line to the east to the Arroyo Isaac from which it was re-diverted by the dam of the same name. There were several other unimportant diversions, viz.: from the Arroyo Casundit by the dam Lugsujin; from the Zapote River by the dam Ligas. The sequence of events in this estate were probably about as follows: (1) The irrigation of the land around Perezdasmarinas by the dam Lugsujin; (2) the irrigation of the land around Paliparan by the dam Embarcadero; (3) extension of (1) by the San Agustin system; (4) extension of (1) by the Trapiche system; (5) reinforcement of (3) by the Pason Castilla dam; (6) utilization of the drainage of (2) by the weirs Baluctot, Pason guaya, Bocal, Bucod, etc.; (7) utilization of stored waters by the Molino dam.

BIÑAN. The writer knows very little about the Biñan estate beyond the fact that its irrigation is comparatively primitive. No map of it is presented, and it has not been of any interest since American occupation.

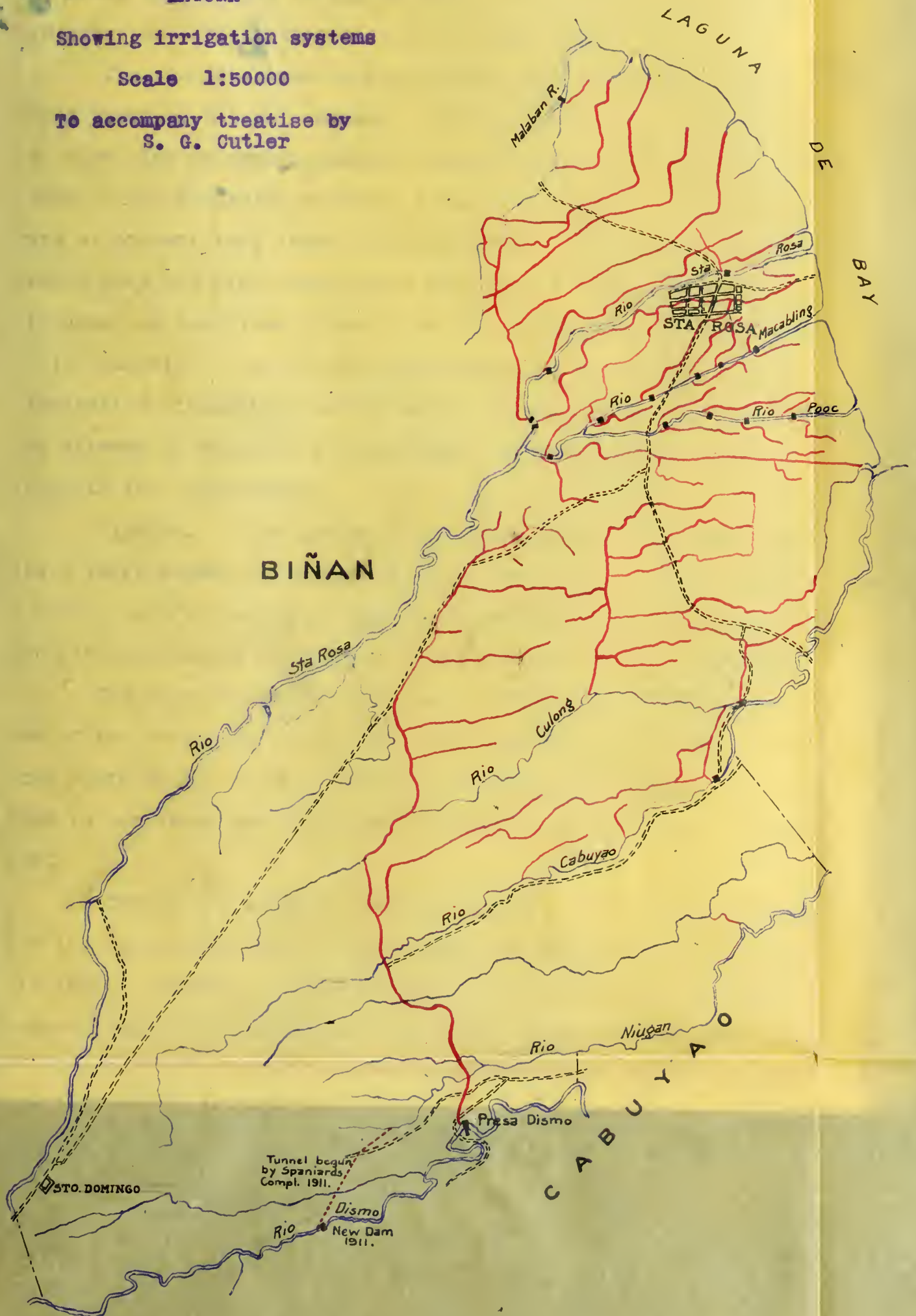
STA ROSA. The Santa Rosa system (Plate XVI, page 95) in Laguna province, presents phases very different from those before mentioned. In the first place the diversion is by means of two separate systems. The first of these is by means of a dam in the Dismo River and a long canal. The streams crossed by the canal are not in very deep channels, so that instead of costly works it was only necessary to build small masonry spills in the stream beds below the canal. It was the practice in the season when these beds were dry to let water from the canal enter them and flow down them to various points where re-diversions were necessary.

MAP OF THE STA ROSA ESTATE LAGUNA

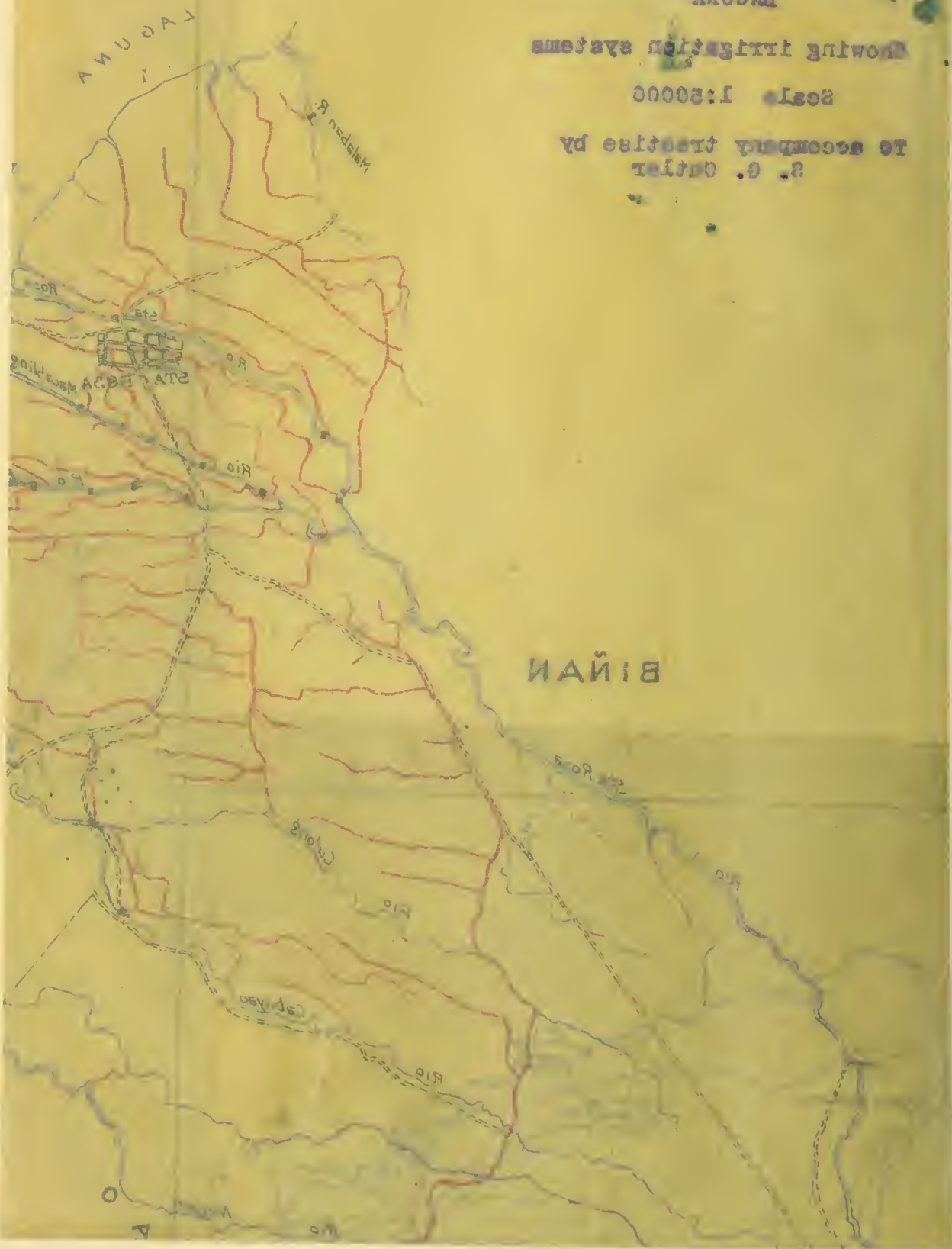
Showing irrigation systems

Scale 1:50000

To accompany treatise by
S. G. Cutler



TO BE COMPLETED BY THE USER



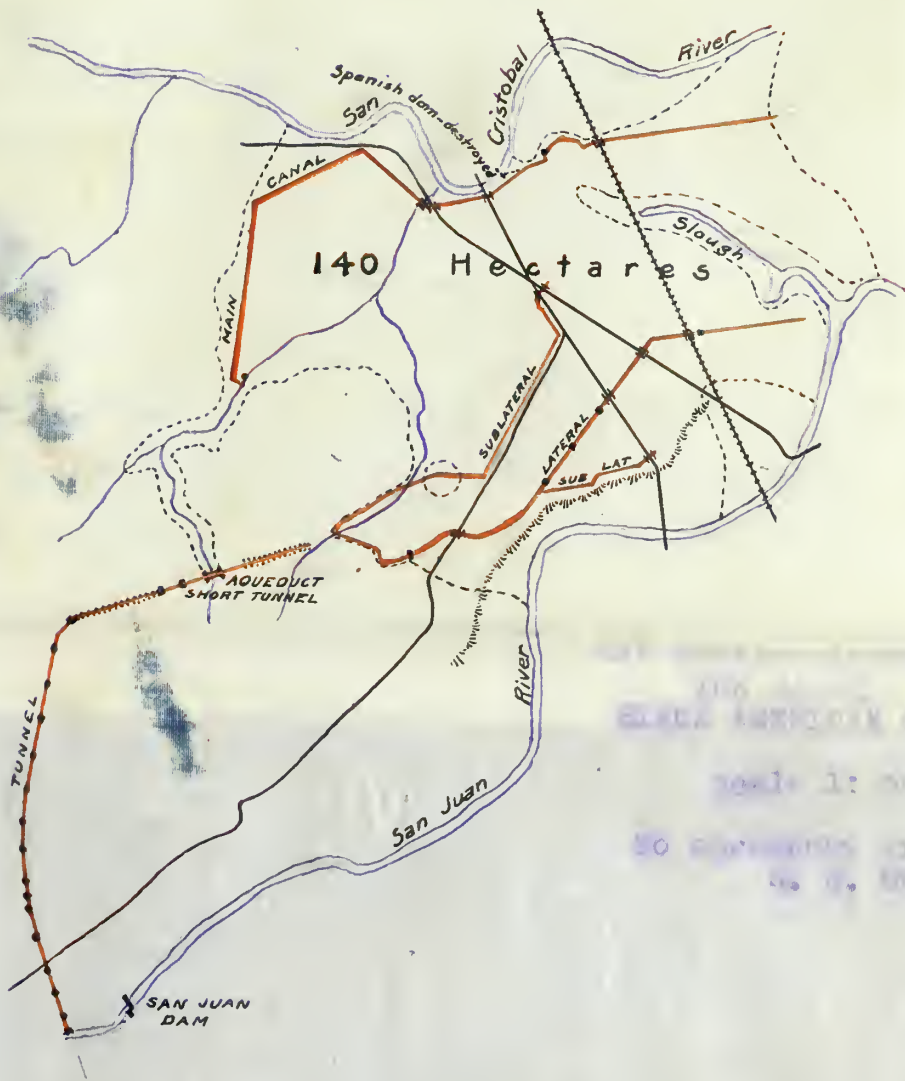
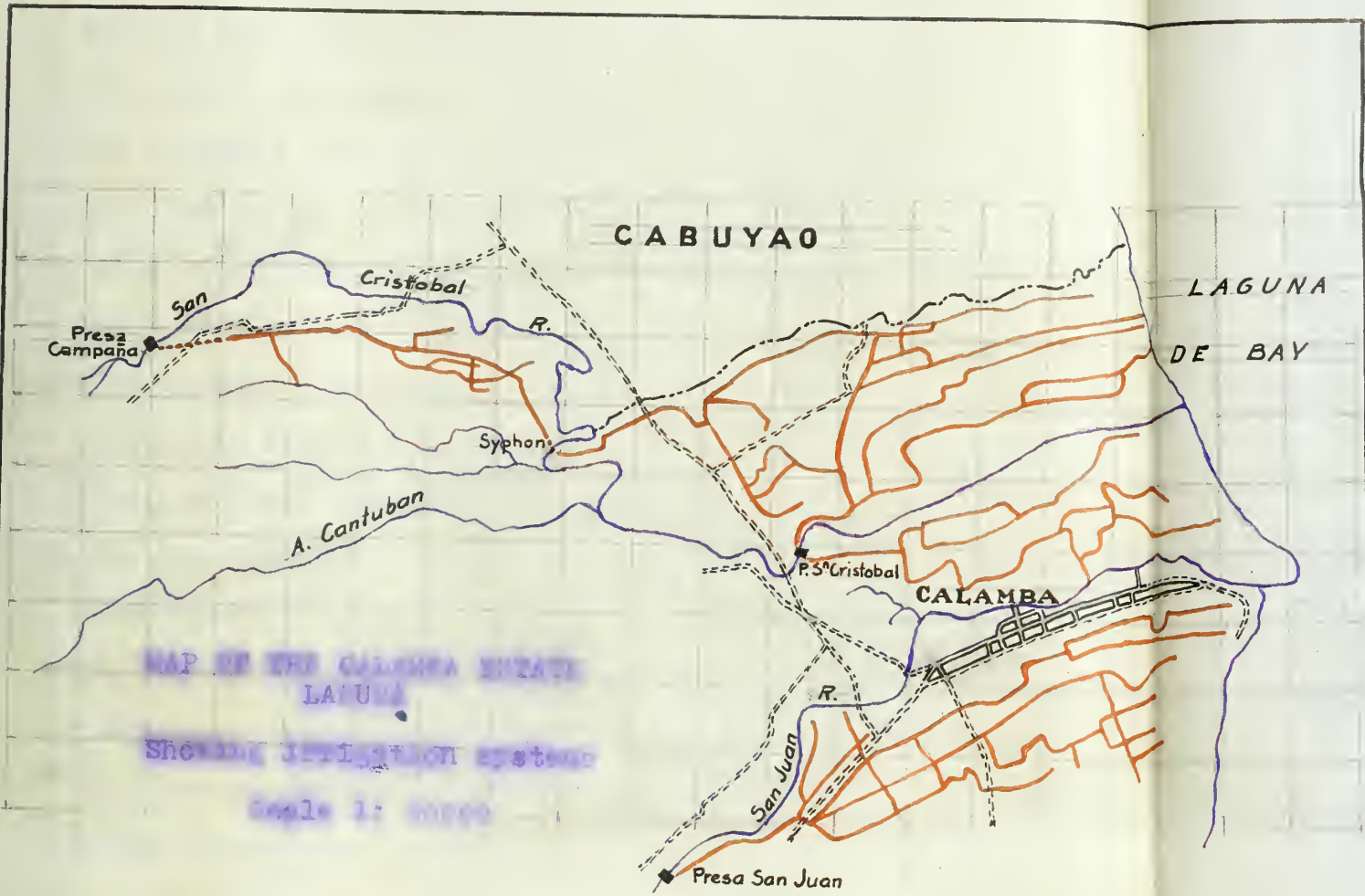
A very complete scheme for the use of drainage water was employed in the irrigated lands. At intervals of about two kilometers or so, a cross ditch would be dug to collect the surplus in the supply ditches and re-distribute it to the land below.

The second scheme of distribution was undoubtedly partly brought about by natural causes. The Sta Rosa River being diverted at some time of unusual height probably made itself new channels in some of the diversion ditches, because it finds its way to the Laguna at present thru three distributaries. It is almost inconceivable that the river could have done this without artificial assistance, as its slope is steep and the stream is not at all deltaic in character. At any rate the happening was fortunate from an irrigation standpoint, as the water is very easily raised from these streams by means of a great number of small masonry weirs with slots for flashboards.

CALAMBA. This system (Plate XVII, page 97) tho small presents a large number of different supply methods. It has probably the most plentiful supply of any of the estates in the San Juan River (the largest in the vicinity) and the San Cristobal River.

The first diversion made was in 1760, when the Spanish owner of the estate built the large San Juan dam and irrigated land to the south of the river. Shortly afterwards another dam was inserted in the lower San Cristobal, irrigating on both sides of that river.

The latter however proved faulty and after being destroyed twice the Dominicans were forced to seek new methods of irrigating their land. Finally in 1885-90 two new diversions were started. The first, which was completed, took water from the south side of



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the San Cristobal at the Campana dam thru a tunnel 600 meters long, from which a main canal carried it to the bank of the same river further down. The water was carried underneath thru a very serviceable inverted cast iron pipe syphon and irrigated north of the San Cristobal River. The second was a tunnel taking off on the north side of the San Juan River at the old dam. It was to have been about 1200 meters long, and its lower end was to have been joined by canals. The work was however cut off by the insurrection before the tunnel was graded or the canals opened. The system has since been completed by the Americans, and irrigates between the San Juan and San Cristobal Rivers.

No special interest attaches to these systems hydraulically but from a construction standpoint they are well worth study. The writer was fortunate in having been specially acquainted with this most masterly collection of works in Calamba, and will use information gained therefrom freely in what follows.

COST OF CONSTRUCTION.

This subject can be but briefly treated. Little is known of the cost of irrigation works, the Friars very naturally keeping it dark. As previously mentioned a good deal of the labor was compulsory, and much was probably freely given, and hence no estimates made by the Friars can more than approximate the cost of the works, since the tenant was paid theoretically for much of his work in spiritual ministrations. It is certain that most of the smaller canals were dug by the tenants absolutely without pay, simply under the direction of the Friars. The structures constitute the only

considerable direct charge, as they were probably erected by contract or paid labor, the time of erection being too great for conscription.

Another fact which renders the subject difficult of treatment is that the works were erected at widely different dates, from the middle of the eighteenth century till nearly the time of the American occupation. The erecting of the first structures is veiled in obscurity, even the builders names being forgotten. Perhaps 20 per cent of the works were built between 1850 and 1880, but it is useless to generalize from that, as the few estimates we have can give no notion of the smaller costs of former times. It must be noted however that the costs would vary nearly as the prices of labor. Building of adobe stone, tunneling with picks and wedges, and using no steam appliances -- everything was hand made and hand run.

The wage of the Filipino is continually increasing and at a higher rate than his cost of living. At present the current wage averages 70 centavos, the writer remembers it to have been no higher than 60 ct. in 1908; in the days of the occupation it was about 40 ct. The comparison of the estimates with current prices, together with information on the subject shows that in 1850-80 the wage (including cost of subsistence furnished) could not have exceeded 15 to 20 ct. How much lower it went in the days of slavery and barter it is impossible to say.

The principal material used, lime cement, has varied little in price, altho probably somewhat in quality during the time considered.

An estimate of the cost of the San Cristobal dam, built

by the Dominicans in Calamba in 1885 follows. This dam is one of the last of the erections and very complete plans and reports were made of it. The price, both on account of the date and of the troublous times, is probably as high as it became under Spanish rule. Besides the estimated prices, the writer has inserted (1) the lowest figures actually obtained for the class of work at present, and (2) between * * the usual estimates at present.

ESTIMATES BY MANUEL RAMIRES OF COST OF CAMPAÑA DAM.

| | | |
|----------------------|--|-----------|
| 1. | 528.4 cu. m. earth excavation @ ₱.10 (.30) *.50* | 52.84 |
| 2. | 1585.3 cu. m. rock excavation @ ₱.20 (1.00) *2.00-5.00* | 317.06 |
| 3. | 845.478 cu. m. hyd. lime mortar @ ₱3.50 (15.00) *30.00* | 2959.17 |
| 4. | 2455.968 cu. m. lime mortar @ ₱3.00 | 7367.90 |
| 5. | 54.218 cu. m. cut stones @ ₱4.50 (5.00) *10.00* | 243.98 |
| 6. | Temporary cofferdam | 300.00 |
| 7. | Temporary spillway | 150.00 |
| 8. | Auxiliary canals | 200.00 |
| 9. | Ware houses and storehouses | 100.00 |
| Total Cost | | ₱11690.95 |

Unless this is a woeful underestimate, or unless it was the custom to make closer estimates than at present, it will be noticed that prices in general have more than quadrupled since that time. Altho it is not certain, the size of above quantities makes it probable that items 1, 3, 4, 5, 6 and 7 refer to the dam, and items 2 and 8 to the tunnel and nearby main canal. The syphon does not appear to be included, and must have been fairly costly. If

the writer were called upon to estimate the same works at present, he would not figure less than ₱50,000 for the dam, and ₱18,000 for the tunnel -- roughly six times the above. The price of rice has not more than trebled since that time.

The above system gives excellent dry season irrigation on some 400 ht., and probably increased the crop by at least 80 per cent. The gain could not have been less than ₱50 per hectare at that time. Extra carabao and implements incident to the added work would not exceed ₱10.00 per hectare per annum; and with an equally divided crop we find that at least ₱10 per hectare gain must have resulted to the Dominicans, or ₱4000 on the whole area. The cost of administration would not have been increased, since the land was already tenanted all the time, and the maintenance of the system under the prevailing order would have been attended to by the tenants. Increasing the estimate of the cost of the system nearly 100 per cent to allow for some items to which the writer can not reconcile himself, there still remains a return of some 20 per cent on the investment, or with a 50 year sinking fund about 15 per cent, which is very presentable and infinitely above any obtained at present.

It is very likely that this is a very conservative estimate of the average returns; the times were hard, the prices were exorbitant ones on account of the insurrection, and the estimate is probably high. However when it is remembered that about 10,000 ht. had similar irrigation which might be expected to return ₱100,000 per annum, or that at similar prices the systems must have cost in the neighborhood of ₱1,000,000, the magnitude of the work can be appreciated. At present costs and values, the annual return

would amount to about half a million pesos a year. Perhaps, had the political outlook been favorable, the Friar Lands would not have sold for ₱14,000,000.

It has been wondered that some of the larger works irrigate so little land. The reason can be seen above. In early times it would have needed very little land to give respectable returns on a comparatively costly system. Then again in the days of actual slavery and of the old Spanish haciendas (previous to the Friars), the actual outlay was evidently almost negligible.

PART IV. PRESENT CONDITIONS OF THE SYSTEMS.

REHABILITATION WORK BY THE AMERICANS.

The evaluation of irrigation works attempted by the Philippine government upon purchase can not be considered to more than approximate the true value of the works. As little was known regarding them, and still less consideration was given their important part in increasing the worth of the rice lands reached by them, their full importance did not develop until later.

General authority to investigate the irrigation works on the Friar Lands of Cavite was given to the Governor General by cable on April 25, 1905, and on March 16. Mr. H. F. Labelle, hydraulic engineer, was directed to investigate the condition of irrigation on the Naic estate, and later (May 10) on all the other estates of the province. Mr. Labelle visited about 50 per cent of the dams and irrigation works, including all the most important, and made estimates for the repairs thought necessary, the latter being principally the insertion of washed out aprons and the cleaning of ditches and tunnels. He recommended that these works be started at an early date, foreseeing that a delay would greatly increase the amount of work to be done. His estimates for repairs were as follows:

| | |
|----------------------------|--------------|
| Imus | ₱3,600 |
| San Francisco de Malabon , | 2,400 |
| Sta Cruz de Malabon . . . | 2,300 |
| Naic | 1,800 |
| Bancod Palauit System . . | <u>1,200</u> |
| Total | ₱11,300 |

The above estimate was supposed to repair works to irrigate about 26,000 ht. It has been greatly exceeded since, altho much work has been done in addition to that outlined by Mr. Labelle. Mr. Labelle remarks in passing that he found the works of the Imus estate in much better order than those of the neighboring ones, and surmises that the San Francisco and Sta Cruz estates were abandoned earlier, on account of the insurrectos. The latter were equally or more active in Imus, but in any case all works were in disuse for five or ten years preceding the American occupation.

Mr. Labelle estimated that at current rates of labor it would cost ₱8,000,000 to replace the works in Cavite province, and he pays considerable tribute to the work of the Friars in the course of his report which is long and extensive.

It is interesting to note that, on December 18, 1904, previous to the taking up of the repair work by the government, the Municipality of Naic had already enacted a resolution that the property holders benefited by the irrigation should take the preservation of these systems upon themselves, and to that end imposed a tax of ₱1.50 per hectare. This resolution was forwarded to the Attorney General for consideration, but of course it was rejected since the land was public property.

Mr. Labelle's report was submitted on June 8, 1905. On August 15, 1905, Mr. D. C. Shanks, Provincial Governor, wrote a letter urging the assignment of a competent force for administration and repair, stating that due to the lack of centralized control the systems were rapidly deteriorating. Mr. Labelle had also urged the appointment of a competent engineer to oversee the repairs on the Cavite systems. Accordingly the work was placed un-

der the control of the district engineer, Mr. E. J. Westerhouse, who on September 17, 1906, made the following re-estimate of cost.

URGENT BECAUSE OF DANGER TO
EXISTING WORKS

Imus:

Julian dam ₱3,000.00

Molino dam 1,500.00

Guillermo dam 300.00

Malabon:

Palauit dam 2,500.00

Policena dam 1,500.00

Marcelo dam 600.00

URGENT IF BUREAU OF LANDS
HAS USE FOR THE LAND

Imus:

Bucal dam ₱1,500.00

Baluotot dam 200.00

Mabilat dam 1,600.00

Manuel dam 2,100.00

Sabang dam 200.00

Sta Cruz:

Tres Cruces dam 800.00

Legidero dam 1,000.00

Dominico dam 500.00

Malabon:

Antigo dam 1,000.00

Total ₱9,400.00

Total ₱8,900.00

Early in 1906 an appropriation of ₱25,000 was made to cover these and other repairs. On June 16, 1906, Mr. Westerhouse reported that 1300 cu. m. of dirt had been removed from the Bancod tunnel, and that four sections of it were complete, 5250 meters; that the defective arch lining had been removed and concrete substituted; and also that six shafts had been lined with concrete. This work had cost ₱8,247.09. On July 7, 1907, Mr. Westerhouse presented an estimate of ₱5,068.29 for the repair of Molino, Marcelo, and Julian dams, Imus. Extensive repairs had been made to the tunnel leading from the Molino reservoir, including the re-arching of the first

ten meters which had caved in. At Marcelo a hole had been washed in the apron, and it was necessary to bridge this by a ten-foot concrete beam, upon which the new apron was built. At Julian a new wing was built to prevent water's washing around the sides of the dam.

Turning now to the Laguna work, it was recommended on April 25, 1905, by Mr. Sherfey, Provincial Supervisor of Laguna, that surveys be made to determine the condition of works on the Calamba estate in that province. On May 26, 1905, Mr. Max Dobbins was detailed to take up this work, and during the following months made a very complete survey of the irrigated lands in that hacienda. The repairs recommended by Mr. Dobbins included the insertion of a new apron in the San Juan dam. He stated that in his opinion the original apron was carried across the river on arches, which later broke thru. He estimated ₱521.00 as the cost of repairing this apron. On September 21, 1905, Mr. Dobbins reported on the north systems of Calamba, irrigated by the Campana dam. He recommended the replacement of the apron of the dam which had been washed out by the floods, the cleaning of the tunnel intake, and the blowing out of the syphon, at a cost of ₱2005. This work was also included in one of Mr. Westerhouse's reports, -- the repair of the San Juan dam (₱ 600) as urgent and the repair of the San Cristobal dam (₱2000) as necessary when the land required irrigation.

The repairs to the apron of the San Juan dam were made in 1907, a concrete beam being constructed to support the apron slab across the hole washed out below, and a vertical curtain wall being sunk to rock. This with the repairs in Cavite made a total of ₱20,274.96 expended by Mr. Westerhouse out of the above mentioned

appropriation. Besides this various repairs were made in Lolomboy and Sta Maria Pandi estates, amounting to ₱1239.23. No work seems to have been done on the Campaña dam, altho the syphon below it was blown out by the local Friar Lands agent.

Up till this time the administration work by the Bureau of Lands had been done separately by a Superintendent of Irrigation appointed in September 1905 by the Bureau with a corp of native assistants. His expenditures amounted in 1906 to ₱6020.15, and in 1907 to ₱17,026.67 -- almost the whole of these amounts having been expended in Laguna and Cavite.

In the latter part of 1907 it was arranged that the Bureau of Public Works, should pay a portion of the salary of the Superintendent, who should not only look after the administration but also the repairs. Mr. J. D. McCord, who had been foreman on most of the previous repair work, was given the position. The total of estimates for repairs and new constructions at this time being ₱59,500, a further allotment of ₱45,500 was made in 1908. Of this ₱10,298.14 was spent on the administration of the estates, and the remainder on various reconstructions and repairs. During Mr. McCords supervision a new apron was inserted in the Palauit dam, the apron of the Antigo dam was replaced, the Bancod tunnel repairs were completed, and repairs were made to the Molino dam, besides the cleaning of many short tunnels and the insertion of small concrete falls, aqueducts and culverts.

Early in 1909 the Bureau of Public Works made measurements and started designs for standard headgates to be inserted in the various dams, mostly in Cavite. The final design, as approved by the Irrigation Division, Bureau of Public Works, furnished a stand-

ard type for different sized openings, the essential details of the gate consisting of a combination of steel angles riveted to form guides and inserted in the masonry, a shutter composed of a steel plate with angle stiffeners on all sides and molaave sliding strips, and a screw hoist operated by a wheel at the top of the guides. The gates had either open or closed topped, depending on whether they were intended to be subject to pressure or not. Their insertion took place in the fall of 1909.

By the following spring the gates were proving troublesome and upon complaint of the Bureau of Lands an engineer of the Irrigation Division was detailed to investigate the matter. His report showed that while lack of judgment had been shown in inserting the gates and setting the guides, the former were not in all cases well adjusted to the size of the canals. After some alterations in the setting of the gates, their operation was much improved. The same engineer also found some of the dams again in need of repair. The Molino tunnel had broken thru in one place, and the water under head had risen to country level and made a bed for itself to the opening of one of the tunnel shafts, down which it returned. Several of the gates had washed under, and were no longer serving.

Mr. Dobbins makes no mention in his report, and does not show on his maps, the Calamba tunnel (San Juan River). This was first exploited by Mr. McCord who reported the same to the Bureau of Public Works, and secured an appropriation for cleaning and grading the same.

In April 1909 the writer was ordered to take station in Calamba, and from that time till June of the same year, was engineer for the work. Very little regrading was necessary, the great a-

mount of work being in cleaning out the deposits, since the tunnel being on a low grade was heavily silted. When the alignment of the work was well started, the writer surveyed a main canal to carry 1000 sec. lr. from the mouth of the tunnel to the canal which previously irrigated the lower San Cristobal district from the river of the same name, thus giving a new supply to an old distribution system. No points of special interest occurred in the survey. The tunnel and main canal were both graded to 1:1000, a 1 x 1 meter standard headgate was inserted at the head of the former, and in the fall the water was diverted from the San Juan River without incident. In addition to the above, the work done on this estate has included the re-banking of many of the canals of the San Cristobal system, the cleaning of all the ditches, and the building of a large number of culverts and falls -- some of the latter by the Manila R. R.

In April 1909, the writer accompanied Mr. McCord to the Sta Rosa estate, and went over the line of the uncompleted tunnel. Shortly afterwards he was authorized to make an investigation of it, which showed that about 340 meters of the 1350 meters length were entirely unexcavated, and that 320 meters in addition would require heavy grading. In May, 1909, the writer received authority to make an investigation and survey of the entire Sta Rosa estate distribution system, which was done, much of the information in that report being embodied elsewhere in this paper. The insertion of headgates and diverting weirs, and the replacement of several small dams was recommended. An estimate of ₱9540 for the completion of the tunnel and headworks was made, which has been

somewhat exceeded. A later estimate of ₱12,772 was made for the repair of the distribution system upon which no action has been taken. In March, 1910, about ₱15,000 was allotted for Friar Lands repair, and Mr. McCord started work cleaning and excavating the tunnel by force account, which has been continued, except for a short time when Chinese contractors were in charge. In September, 1910, some trouble developed over the alignment of the work, and as a result the writer was given direct charge of the tunnel and of various other Friar Land operations.

The excavation of this tunnel was completed without incident on December 8, 1910, at a cost of about ₱16,000, and the upper end which had to be heavily graded, was completed on January 22, 1911, at a cost of about ₱2000. The writer also started work on a small new dam which is to be inserted in the Dismo River at the tunnel entrance and which will probably cost about ₱5000. At the same time several falls of a new notched type were inserted on the Calamba estate, and a new lateral opened at a cost of about ₱2000. It is planned to insert many more of the same type here and elsewhere later, after the effect of these has been noted.

In the latter part of 1910, an allotment of ₱50,000 was made for Friar Lands repair, and was put at the disposal of the Chief Irrigation Engineer, most of the writer's work being payable out of it. The remainder is still to be spent -- probably a good part of it -- in a complete topographic survey of the Cavite estates from which intelligent repairs can be made, and part of it in necessary reconstructions in both provinces. As soon as it is possible to arrange matters satisfactorily to all the branches of the government concerned, the work will undoubtedly proceed faster.

This takes the work to the date of the writer's relief on February 4, 1911. At present the topographic survey is progressing on the San Francisco estate, and repairs are to be started to the Ligas dam, Imus.

PRESENT CONDITION OF THE WORKS.

The repairs undertaken by the Americans have been somewhat spasmodic, and can not be said to have more than brushed the surface of these irrigation systems. There are still plenty of examples to show the effect of wear on the old works.

DAM. Aside from a few special cases, the principal effects of time on these structures are: (1) silting up, (2) washing out at the foot, (3) undermining, and (4) leakage. The first is probably of little injury to any but dams having very deep canal intakes.

1. The rivers considered are ordinarily very clear, especially at the primary diversions, but in time of flood they bring down great quantities of brush and silt. The quantitative effect of the silt is rather hard to determine, since most of the ponds have filled in to such a depth that there is comparatively very little stilling of the velocity above the dam in floods. Mr. Dobbins estimates that the pond above San Juan dam fills 30 cm. each 10 years. Its upstream height being 11 meters, this process must have been much more rapid at first, as the dam has silted to within 2.5 meters of crest level in 150 years. The Campana dam has silted 7 meters in 30 years, which is at a much more rapid rate. Probably the silting to within two or three meters of the top is accomplished at an average rate comparable to the latter, after which it is even slower than Mr. Dobbins estimates.

With the exception of a few in very small sediment-laden streams, none of the dams are completely silted up. Evidently the spillway itself serves as a scouring agent during floods, after a certain height of deposit is reached. In the cases of a few very small wiers, the wall has completely silted, the stream continuing its course directly into the canal. As far as the dam itself goes, the effect of the process is more beneficial than otherwise, forming an additional element of safety by reducing the direct water pressure and also by helping to prevent seepage. On the other hand almost every diversion canal is filled up near its mouth, and a great many of the tunnel entrances are in need of cleaning.

The few dams which possess scouring sluices are not in much better condition, as they are somewhat difficult to open and have therefore not been used. The writer can obtain no record of the San Juan ever having been flushed; and the Molino storage dam, altho having been sluiced several times, is badly silted, as the sluice is narrow and only clears a small width of the reservoir.

2. With the mode of construction much used by the Spanish -- the curved downstream profile continued into a flat apron, -- the results have been uniformly disastrous. The water forms a fall at the downstream end of the apron and wears out the soft bed. The cavity thus formed eats back beneath the apron until finally the masonry of the latter drops into it. The same process of cutting then continues beneath the dam. Examples are numerous in which this process finally ended in the complete destruction of the dam. The first Balayungan dam in Imus was thus undermined, as well as the lower San Cristobal dam in Calamba. Almost all of the large repairs mentioned under American management have been in re-

placing the portions of aprons and dams thus damaged. Marcelo and San Juan were thus repaired among others. Ligas is in very bad condition at present from the same cause, while almost every one of the dams which have not been repaired shows unmistakable signs of the bad effect of this form of construction.

3. Undermining proper, that is, the destruction of the dam by water's seeping between the masonry and the foundation, is not frequent. In many cases however, this condition is met with where the masonry adjoins the side walls of the canyon, where sufficient care was not taken with the bonding. This is the case at Policena, Dismo, and many others. Its infrequency however must stand as a recommendation of the materials and the workmanship, as it probably occurs only where a seam is found in the side walls of the river bed.

4. Seepage thru the body of the dam is more common than the above, altho various dams differ in the nature and amount of this action. The writer has never seen a dam where the amount of leakage would appear dangerous to the structure.

The largest of the dams, Tres Cruces, Policena, Molino, and San Juan seem remarkably free from dangerous seepage thru the masonry. In dams where it does occur, it starts near the crest, in a slight dampness on the masonry, becoming more and more noticeable until a film of water is formed, which in the aggregate becomes quite a stream near the toe of the dam. This does not appear to increase in quantity with an added head of water.

The condition of the masonry itself, aside from these structural results, is pretty uniformly good -- in fact the rela-

tive condition of the work does not appear to depend on its age but entirely on the quality of material used. The San Juan dam in Calamba, and the Antigo in San Francisco are in excellent condition as regards masonry, altho they are both very old. On the other hand, where the stone was soft, the falling water has often worn it considerably.

However, as before stated, the masonry itself is well adapted for the work, and as far as actual erosion goes none of the dams are yet in need of repairs. In many cases a great deal of brush and grass has taken root on the abutments and wings, and should be carefully cleared, as its roots soon reduce the rock to its original clay.

TUNNELS. The principal effect of time on these structures is shown in silting up, caving in of roofs and shafts, and various combinations of the above. Of these the first is by far the most frequent. This has been due both to the low gradients of many of the tunnels, and to the blocking up by brush or silt of the tunnel itself, or of the ditch above it, or of its mouth at the river. Of course this does not include the uncompleted tunnels, which still water soon fills with mud.

The tunnels, almost without exception, have been cleared of a mixed deposit from 0.3 to 1.0 meter deep, or still require it. The numerous shafts, being open or easily opened, have served as collecting places for all sorts of rubbish, both accidentally and by design. Sediment carried by the stream flowing thru the tunnel is caught behind these checks, and has formed layers of greater or less depth, depending on the height of the still water. This was the case of the Bancod tunnel. In other cases this was due to the

closing of the canals below the tunnel, which backed water into the latter, or to the fact that the canals had insufficient grades. The Calamba tunnel was thus almost completely closed. In a few cases the deposit in the river bed above the dam has risen so high as to silt up the mouth of the tunnel. This process is going on and will soon become serious in the tunnel leading from the Campaña dam, Calamba.

Serious cave ins of the roof are infrequent. The tunnels were always built arched, and the clayey rock is capable of a good deal of settling without rupture. Where cave ins have occurred, they have been where the rock has a gravelly character. Cave ins of parts of the shaft walls are more frequent, which may be due to planes of seepage entering them, to earth-filled bedding surfaces in the rock, or to the action of the sun on the upper rocks. Where the shafts have been provided with curbing, the latter is in good condition; but where they have been arched over, the arches have sometimes fallen in.

The effect of the stopping of the tunnels is limited in most cases to the deposit of a strata of mud; but in some cases it is more dangerous, as in the case before cited, near Molino, where the water has been forced up one of the shafts and out onto the country.

In general the rock of the tunnels is in much better condition than one would expect, which is a great surprise to engineers who are used to the universal lining of tunnels in soft material.

Of the minor dams, weirs and gates, most are in very good condition. Their structure, being in general not so durable as that of the large dams, has in cases suffered, the floors being

washed out and the abutments undermined.

CANALS. The canals have already been described. In general they can be treated in two classes. Those in deep rock cuts have changed but little -- the walls are still vertical and firm. Those in earth have deteriorated into creeks, cut to rock in places, or spread into wide swampy sloughs. The writer has already given his opinion on the transformation of these canals.

The minor ditches and canals are in various conditions depending on whether they have been in use or not. Those which have been in use are generally open continuously, but have been much broken by the insertion of weirs and branches. Where not in use, one generally can find only parts of them, and where it has been advantageous they have been plowed across or transformed into trails. A careful inspection is thus necessary to learn where they originally headed.

ATTITUDE OF THE LANDOWNERS. Perhaps the most interesting phase regarding the present condition of these irrigation systems is the way in which the landowners regard them, and the bearing of that attitude on plans for improvement.

For ten or fifteen years they have afforded the works almost no maintenance or repair; nothing beyond that absolutely necessary to bring the small parcels cultivated in the days of the insurrection under water. When the Americans first took up the maintenance, the landowners were apathic, and altho a great many have started additional rice culture since, and have paid the extra price for irrigated land, the long idleness of the works, the cost necessary to repair them, and the large scale of the work planned, ren-

der it almost certain that the farmers will not understand and will resent the institution of water rent as a return to past methods of extortion.

ESTIMATES OF VALUE.

ECONOMIC FEATURES. In describing the engineering features connected with these systems, we have already taken up the probable economic value of these works at the time they were built. This must not be confused with their present value. The difference is due to many causes -- some of which will be mentioned. First undoubtedly comes the deterioration of the works, which has not been lessened by continuous maintenance. In the last article this has been taken up at length, and the nature of present necessary repairs has already been described. Secondly, there has been much change in the respective crop areas, rice areas having generally increased. Where the supply is limited, this renders the water more valuable. Third, the administration methods must of necessity have changed. Closely related to this is the change in feeling of the landowner towards the owner of the irrigation works. Fourth, there must be taken into consideration the great difference between the cost of construction and the sum which would be required to replace the works. Fifth, in the light of more careful investigations, it will probably be found that many of the systems are more or less valuable than formerly supposed.

The writer will not attempt to discuss all the above factors as he lays no claim to prophecy; but will merely attempt to outline the trend of events and try to give some idea of the value of the works at present.

It will be remembered that Mr. Labelle estimated the cost of the replacement of the Cavite works with the then rates of labor, to be ₱8,000,000; and that these works were capable of irrigating 18,500 ht. In 1907 Mr. J. C. Mulder made the following estimate of the value of works on the Naic estate: dams ₱125,000; tunnels ₱25,000; canals and laterals ₱20,000; total ₱170,000. This would irrigate approximately 2400 ht. These are but rough estimates, and differ widely; but serve to show the general value placed on these works in official communications. The writer wishes to take up three different phases of the subject in the following discussion.

PURCHASE EVALUATION. In 1904 Sr. Villegas made an approximate estimate of the value of the Friar Lands. This has not stood the test of time, but such as it is it shows what value was put upon the works at that time. In looking over his figures we see that areas classed as first and second class rice land were evaluated at about ₱150 per hectare and all other land except town lots at ₱50 to ₱60 per hectare. Since the land classed above is supposed to be irrigated, it seems only fair to assume that the ₱90 difference was due to irrigation. The writer has taken the liberty to substitute approximately the correct irrigated areas in Sr. Villegas valuation, his figures being so manifestly guesses, and presents the following list.

| ESTATE | TOTAL EVALUATION | EVALUATION IRRIGATION WORKS | ₱90 x IRRIG. AREA | % IRRIG. TO TOTAL EVALUATION |
|---------------|---------------------|-----------------------------------|-------------------------|------------------------------------|
| Naic | ₱ 770,978.76 | ₱ 90,305.76 | ₱ 216,000 | 39 |
| Sta Cruz | 682,456.87 | 50,000.00 | 216,000 | 40 |
| San Francisco | 1117,250.00 | 100,000.00 | 342,000 | 40 |
| Imus | 1605,303.64 | 80,000.00 | 900,000 | 61 |
| Binan | 497,865.22 | 12,000.00 | 90,000 | 21 |
| Sta Rosa | 703,024.92 | 12,000.00 | 180,000 | 27 |
| Calamba | 1102,430.70 | * | 90,000 | 8 |
| Total | ₱6479,310.11 | ₱344,305.76 | ₱2034,000 | 37 |

One can not believe that the evaluation of irrigation works was approximately their cost of construction in Spanish times; but as a whole the percentages show up as might be expected. The Imus estate is the most completely irrigated of all, and the Calamba estate the least. Nearly 40 per cent of the money paid for the estates, if we believe the rational results of the above table, was paid for irrigation works or improvements depending on them; or, we may say that considering depreciation and the probable future necessity of replacement, the government was willing to pay ₱2,400,000 for the irrigation works.

COST OF REPLACEMENT. Next let us consider the cost of replacing these works. This also is an approximation. The evaluation is based on the size and number of works on the various estates, and on the average cost of construction at present.

Naic estate:

| | |
|--|-----------|
| Dams (3) 7500 cu. m. masonry | ₱ 150,000 |
| Small dams, etc. | 15,000 |
| Tunnels, 2 km. | 80,000 |
| Main canals 20 km. | 28,000 |
| Main laterals 30 km. | 15,000 |
| Total for Naic | ₱ 288,000 |

Sta Cruz estate:

| | |
|--------------------------------------|-------------|
| Dams (7) 59,900 cu. m. masonry . . . | ₱ 1,198,000 |
| Tunnels 4.3 km. | 172,000 |
| Main canals, 20 km. | 40,000 |
| Main laterals, 40 km. | 20,000 |
| Total for Sta Cruz . . . | ₱ 1,430,000 |

San Francisco estate:

| | |
|---------------------------------------|-------------|
| Dams (11) 51,600 cu. m. masonry . . . | ₱ 1,033,000 |
| Other masonry structures | 103,000 |
| Tunnels, 6.3 km. | 252,000 |
| Main canals 25 km. | 50,000 |
| Main laterals, 60 km. | 30,000 |
| Total for San Francisco . . . | ₱ 1,468,000 |

Imus estate:

| | |
|---------------------------------------|-------------|
| Dams (22), 93,000 cu. m. masonry. . . | ₱ 1,860,000 |
| Other masonry structures | 186,000 |
| Tunnels, 3.5 km. | 140,000 |
| Main canals, 58 km. | 116,000 |
| Main laterals, 90 km. | 45,000 |
| Total for Imus | ₱ 2,347,000 |

Binan estate:

| | |
|---------------------|-----------|
| Estimated | ₱ 100,000 |
|---------------------|-----------|

Sta Rosa estate:

| | |
|---------------------------------------|-----------|
| Dam (1), 1,600 cu. m. masonry . . . | ₱ 32,000 |
| Many other small structures | 40,000 |
| Tunnel 0.8 km. | 32,000 |
| Main canal, 10 km. | 20,000 |
| Main lateral, 20 km. | 10,000 |
| Total for Sta Rosa . . . | ₱ 134,000 |

Calamba estate:

| | |
|--------------------------------------|-----------|
| Dams (2), 8,320 cu. m. masonry . . . | ₱ 166,400 |
| Syphon, etc. | 16,600 |
| Tunnels, 2.4 km. | 96,000 |
| Main canal, 7 km. | 14,000 |
| Main lateral, 10 km. | 5,000 |
| Total for Calamba . . . | ₱ 298,000 |

Grand Total . . . ₱ 5,965,000

The cost of replacement at present would average ₱268 per hectare of irrigated area.

CROP VALUE. We have previously learned that the average ef-

fect of sufficient irrigation is to increase the annual output about 100 per cent. A very conservative estimate of the money value of this increase would be ₧100 per hectare per annum. The writer's observations, added to those of others, goes to show that about half the area can be irrigated to some extent twice a year; while on the other hand there will be a great benefit, due to dependability, to the land on which but one crop is raised. The labor necessary to raise an extra crop would not cost over ₧20 at most. These figures would indicate that under efficient management, a net profit of ₧800,000 per annum on the well supplied land, and ₧100,000 on the land only irrigated once, could be expected. Were a 10 per cent tax levied on this annual value of ₧900,000 a sinking fund could be established which would completely rebuild the systems in 50 years, besides furnishing a reasonable amount each year for maintenance.

From the above discussion the conclusion can be drawn that the gain warrants not only the maintenance of the present systems, but would justify the new construction of similar systems, were it necessary, at a cost of ₧6,000,000. No engineer, acquainted with present methods and costs, will after making an investigation of the works, deny that the writer's estimate is low.

It must be remembered that there are very few indications of actual giving out as yet, and that such as have occurred are in the less expensive works -- small light dams, canals, and laterals. Dams similar to the larger ones are still serving in Spain at an age of 400 years. The San Juan, and the Antigo dams, the oldest, are in good condition at an age of over 150 years. Furthermore it must be remembered that the great majority of the dams have been built within the last 60 years.

CONCLUSIONS. The writer would say that on an average a 200 year replacement fund would be sufficient to care for the dams; that all tunnels will have to be lined or opened inside of 30 years; and that repairs equivalent to the replacement of all canals will be necessary within the next ten years. This would amount to an annual appropriation of ₱14,000 for repair and replacement of dams and like structures, ₱25,000 for repair and lining of tunnels, and ₱39,000 for the regulation of canals and ditches -- a total of ₱88,000 annually. This would amount to about 10 per cent of the total value of the irrigation.

The actual annual appropriations have been much less than the above estimate; but while it is generally believed that they are excessive, the fact that they do not decrease as they were expected to, that necessary repairs are accumulating, and that the general regime of the works have not improved, goes to show that the appropriations have not been sufficient.

In the time of the Friars the irrigated areas were not so widely scattered nor was dry season irrigation so universally attempted. One can not figure the exact money value of the water rental which they obtained; but probably the ₱2.00 per hectare which was decided on previously was deduced from some actual or assumed Spanish rental. This amount is absurd, considering the present value of the water and the rental obtained in other similar tropical countries. There is no reason why land under dry season irrigation should not pay ₱10 per hectare, which alone would give an annual maintenance and replacement fund of ₱100,000. The annual income under the present plans is about ₱40,000 which no engineer in the Philippines regards as sufficient.

For several reasons it would not be easy to bring about the changes proposed. 1. The Filipino had these systems to himself for ten years, paying no rent. 2. He has been taught to regard the government as a benevolent institution. 3. Since at present he is not paying anything for the water, he does not bother to use it in one case out of ten. 4. And much the most important, he can never be brought to understand the collection of a cash tax, and the government could not go back to the share basis of the Friars.

The foregoing estimate can not be applied to any special case where it has been found that a small outlay would irrigate a large additional area or that costly new constructions are necessary in a certain location. It is simply a general average statement of the standing of the systems at present.

To summarize then: The irrigation works make about 40 per cent of the actual and prospective value of the Friar Lands estates. They have an annual value of some ₱900,000, and should at the present cost of work, be maintained and replaced by an average annual expenditure of ₱88,000 -- less than 10 per cent of their value to the landowners. The contemplated tax of ₱2.00 per hectare will not be sufficient for the above work; and by limiting it to that there is no doubt that the future of the works is uncertain.

PART V. CONCLUSIONS.

UTILIZATION OF OLD IDEAS.

GENERAL CONSIDERATIONS. It has been in the administration and use of these systems that the Americans have found many points of strength and weakness in construction; and to just the extent that they profit by past recommendations and warnings, will the systems be of educational advantage to their present owners. The following matters are of importance for that reason.

In considering the general plan of the systems, this point presents itself: The Friars had no general plan, they had no foresight for extensions, they had no real idea of how much land or how much water would be wanted. Perhaps in the days of the first diversions this was unnecessary, the requirements being only to put enough water on the small parcel in hand. But that being done more desirable land was at once observed in the vicinity; when perhaps it would be seen that no more water could be obtained from the existing works, or that the contiguous land was a little too high. The costly and precarious expedients thus necessitated have already been referred to, where a little foresight would have resulted in the correct diversion at once.

The Americans have realized this. The Calamba estate proved a simple proposition; and the making of a good map, together with some additional exploration, has resulted in the gain of about 400 hectares of irrigated land. The Sta Rosa estate is complicated but it was surveyed by the writer, plans were made for carrying part of the supply of the Dismo River into the Sta Rosa River, and a comprehensive tabulation of irrigated areas was made so that correct

apportionment can be made to the various laterals. Sketch maps affording some idea of the circulation and supply on all the Cavite estates exist, which will aid if studied in untangling what at first sight seems an insoluble maze of canals. The Irrigation Division has been planning for some time, and is at present working upon, a comprehensive survey of all the Cavite estates, and once this is completed, it will be only a matter of superficial study to trace out the main lines of supply and treat them as such. There has been too much money expended on the repair of subsidiary dams, not realizing that the head dams of the systems are unaccessible and for that reason often in a precarious condition, may fail at any time, and render all the other work useless. The writer ventures to state that if it were realized how many of the works are really subsidiary, the major part of the operations for years to come would consist in banking these heavily with earth since that would insure stability as the floods in those streams never become dangerous. Nature has done this for some of them, and nature is a good guide.

The Friar's plan of utilizing the creeks can often be used to advantage. The general idea was of course that this should be temporary, and that later diversions could be made from the creeks at any point. A canal is seldom in stable regime, and will eventually if left to itself assume the appearance of a creek; therefore unless a thorough maintenance can be afforded it is in every way preferable to use as many natural creeks and as few canals as possible. The cost of the small re-diversions necessary can easily be met out of the amount saved on construction, maintenance, and repair of the canals.

The building of the Friar Land systems was a gradual devel-

opment. Too many present surveys embrace all land, swamp, timber, and cogon, lying below the imaginary grade line, forgetting the axiom that the Filipino only wants enough. The estimates for such systems are of course costly, and while plans should be made for future extensions they should be developed as needed, not all forced thru together. Given the time required for building such an extensive system as that of the Imus estate and even the necessary capital, the Friars would never have been guilty of the folly of trying to put a greater portion of it in than the land was crying for.

ADMINISTRATION. We can say little of the lessons to be learned from the administration of the systems. It was evidently some actual or assumed grievance in the handling of the Friar lands which projected the insurrection against the Friars. The Filipino is sensitive when approached about his property rights; and the removal of land or water by the government, guarded by never so good legal steps, is questionable in his eyes. Whether the American will succeed where the Friar failed is partly for the former to settle, but not entirely. The ordinary native is incapable of appreciating public domain, and is therefore at the mercy of wiser but less honest politicians who persuade him to their advantage.

Thus far on the whole the American administration has been successful on the Friar lands. Much of the land has been sold with a ridiculously small surcharge for irrigation; but the people, after some demur at even this, have shown that a proper charge or the collection of water rent would be strongly resented. The maintenance tax would be especially obnoxious, since the owner has no notion of "forenand is forearmed". He would rather "maintain" the

system himself, "maintaining" meaning to let it go until the water refused to run, then making such temporary repairs as were perfectly convenient. The collection of the extra rent on irrigated lands was accomplished with not a little friction, and the Filipino having once bought his parcel, force alone will be sufficient to exact another centave from the landowner for water. It is exceedingly doubtful whether the work can proceed with less interruption than that of the Friars.

DETAILS OF CONSTRUCTION. The plan of the Friars of choosing their dam site first is both good and bad. Good in that it often resulted in placing the most important and most inaccessible structure in the system in a position of impregnability, where while the canals could be easily inspected and maintained the dams once in place would go on diverting water for years without notice. The point of weakness in the plan was that it too often limited the irrigated area or the supply of water obtainable at its head. Of course a compromise between the best dam site, the greatest amount of land, and a sufficient supply, is the most rational choice. It is on this basis that much alteration must be made by the Americans, chiefly at the present time, of course, in the sacrifice of irrigated areas to the proper slope in the supply lines; but in many cases doubtless in the extension of the height of dams or the insertion of new crests.

The writer considers, however foolishly, that the use of adobe stone and lime mortar, and the buildings of dams of immense section, such as the Friars built, was the best method under the circumstances. For the most part these dams are great masses of rock, and there are not more than ten of them that require more

than a casual inspection to show their perfect stability. It is not worth while to build for looks or to approach too closely the theoretical profiles, where one's only critics will be a few untutored Malays. The nearest approach to the native hills is the best, and will more probably survive "for all time" without maintenance, than a graceful profile of reinforced concrete. The adobe stone is light, but is cheaper per unit weight than the concrete. The use of cement mortar, is unjustifiable, and should give way to lime.

The most distinct warning conveyed by the old dams is against the ogee slope in soft rock. Some of the water will invariably instead of flowing off rapidly strike small holes in the bed, and preserving its velocity churn around and enlarge them until gradually a large hole will be worn in the dam toe in which fragments of rock will batter and scrape until an immense pit is formed. This pit cuts back into the dam and finally results in the falling of the dam into the hole during some period of heavy pressure. Altho only a few of the dams have thus failed, it is a tribute to their tenacious structure, as many of them are half undermined by these pits. The sight of these pits and the realization of the manner of their formation, has turned a good many engineers from their ogee enthusiasm, at least as applied in adobe rock.

In direct conformity with the otherwise simple construction is the absense of sluices, falling gates, or other devices on the crests of Friar Land dams for the passage of floods. These devices, while saving much expense on dams subject to continuous and careful maintenance, are useless when left to the mercy of the native, to whom all inspection is "manana". He would always be on

hand to open them the day after the contingency. The only plan is a massive, durable spillway over which the swiftest and deepest floods will roll. The one danger in this plan, and the occurrence which undoubtedly causes much damage, is the entrance of flood water into the ditches. This was controlled in some cases by waste sluices. The latter are still required; for altho durable gates have been installed at almost all supply heads, there is no assurance for their regulation.

While accrediting the Friars greatly, too much can not be said against the lax methods of tunnel and canal building practiced by them, particularly the crooked lines and the uneven and insufficient grades.. Probably the most costly work to be done by the Americans will be the straightening, re-grading and lining of the tunnels. The latter point seems never to have been considered, at least more than very locally; and will cost very highly when finally necessary, as necessary it must be in a few years since even good rock will not stand constant erosion for an unlimited time. Probably the best means of lining will be that used by the Friars where they attempted it, and recommended by the writer as cheaper and more adaptable than concrete of any description, namely adobe masonry arches set in lime mortar. It is doubtful whether the Americans will attempt any new tunnels on the Friar Lands; but if they do with modern surveying instruments and ventilating devices, the shafts could well be three times as far apart as the Friars made them. As sunk by the latter, the shafts on an average tunnel must have cost a third as much as the line proper.

The slope of the canals can in many cases be changed to advantage. In a good many locations, where the supply line is on

a low grade for the most of its length, there will be found places where the drop is very rapid for a short distance. The insertion of drops at the lower end of such places, where the water can be raised nearest to the field level, could be made at trifling cost; and if well designed and regulated would not only supply the land permanently and satisfactorily, but would improve the regime of the canal greatly, and could be easily used as measuring weirs. The placing of a great number of small diversion boxes and sublateral gates is necessary for the correct distribution of the water.

We can not hope, per media of unaided water men for whom the native farmer has little respect and no love, to promote the same results as were obtained by his masters, the Friars; and we should indulge ourselves to the extent of a few cheap locked supply gates. The Irrigation Division has already designed a large variety of screw gates; but a smaller and simpler, and equally efficient type is even more urgently needed.

ADJUSTMENT OF SUPPLY.

In the preceding article some of the most evident phases of the problem which confronts the Americans have been dealt with. There remains a subject which the writer is rather loath to discuss, since his data are meagre and may soon be proved faulty. But if it will be remembered that his figures are mainly the results of measurements on inaccurate maps and of his personal estimates, he will venture upon the subject. It must be understood however that he does not claim accuracy for his results, but believes his method of treatment should be pursued on the Friar Lands when more exact data become available.

Some idea of the hydrographic features of the country have already been given, and it has been shown that the average available flow off during the rainy season, is about 50 sec. lr. per sq. km., and in the dry season from 3 to 10 sec. lr. per sq. km., in the larger and smaller streams respectively.

In Table 2, page 132, the total irrigated land has been segregated into units, each of which may be said to be formed of fairly connected works. Table 3, page 133, gives the drainage area tributary to each supply. It is necessary to employ some method of treatment to determine how much land can be irrigated by each supply during two seasons, and how much can be reached but once. The Irrigation Division is at present installing weirs and gages all over the Friar Lands, from the data of which the following method can be carried out almost exactly, but several years of observation will first be necessary.

Starting with the Balayungan River in Naic, we find a drainage area of 65 sq. km. tributary to it. This would probably give a supply of about 3000 sec. lr. in the rainy season, fully sufficient for all the land depending on it. In the dry season the flow would probably be reduced to 600 sec. lr., which would irrigate more than half of the land. Units 2 and 3 would have a supply of 1000 sec. lr. in the rainy season, probably a sufficiency; but in the dry season only a small proportion of the land, about 200 ht. could be irrigated. This is verified in a report by Mr. Mulder, who personally noticed this state of affairs. Unit 4 has a tributary area of 22 sq. km., enough for complete rainy season irrigation; but only sufficient for about 200 ht. in the dry season. The writer has personally observed the unwatered fields of this dis-

Table 2 Segregation of Irrigated Districts in Cavite & Laguna

| Reference Number | Name of Diversion Dam | Sources of Supply | Area | Evaluated as 1 st or 2 nd Class rice land — | Area of Estate |
|---------------------------------------|--------------------------|---------------------------------|-----------|---|----------------|
| | | | Irrigated | | |
| | | | HECTARES | | |
| 1 | Balayungan, Culong-culog | Balayungan R. | 1210 | | |
| 2 | Mabunga | Drainage from 3 | 240 | | |
| 3 | Caysaba (Calumpang) | Caysaba R. | 960 | | |
| Total Naic Estate | | | 2410 | 3119 | 7624 |
| 4 | Saguin - Tres Cruces | Alolu, Caituci, Moralin R's | 830 | | |
| 5 | Legidero, Singo, Pajo | Catibayo, Pastema, Obispo A's | 150 | | |
| 6 | Molino Sta Cruz | Cañas R | 1470 | | |
| Total Sta Cruz de Malabon Estate | | | 2450 | 4001 | 9795 |
| 7 | Bancod-Palawit-Buloc | Naic, Panisayan, Matangilan R's | 860 | | |
| 8 | Ladrone | Ualan R | 720 | | |
| 9 | Marcelo | Ilanilan R | 990 | | |
| 10 | Policena, Antigo | Cañas, Ualan, Drainage from 748 | 1190 | | |
| Total San Francisco de Malabon Estate | | | 3760 | 6500 | 11449 |
| 11 | San Agustin, Casundit | Ilanilan, Nancean, Jasaan R's | 2670 | | |
| 12 | Pason Castila | San Agustin, Drainage from 14 | 940 | | |
| 13 | Lugsujin | Casundit A. | 570 | | |
| 14 | Trapiohe | Tibagan R. | 1650 | | |
| 15 | Baluctot | San Cristobal A. | 220 | | |
| 16 | Pason Buaya (Guaya) | Pason Guaya, Drainage from 18 | 840 | | |
| 17 | Molino (storage) | Alapan, Drainage from 18 | 2210 | | |
| 18 | Embarcadero | Malaguin-ilog R. | 480 | | |
| | Ligas, David | Zapote R. | 300 | | |
| Total Imus Estate | | | 9880 | 8962 | 18243 |
| 19 | | Sorosoro R. | 530 | | |
| 20 | | Carmona R. | 500 | | |
| Total Biñan Estate (Approximate) | | | 1030 | 2039 | 3659 |
| 21 | Various | Sta Rosa R. | 1080 | | |
| 22 | Dismo | Dismo R. | 900 | | |
| Total Sta Rosa Estate | | | 1980 | 2310 | 5470 |
| 23 | Campana | San Cristobal R. | 460 | | |
| 24 | San Juan | San Juan R. | 580 | | |
| Total Calamba Estate | | | 1040 | 4874 | 13673 |
| GRAND TOTAL | | | 22550 | 81805 | 69913 |

Table 3. Contributing Drainage Areas, Cavite & Laguna.

| Main Stream | Drainage Area sq. km. | Tributary | Drainage Area above diversion site | Number | Irrigation systems applied |
|---------------|--------------------------|----------------|---------------------------------------|--------|----------------------------|
| Balaungon | 85 | Balaungon | 65 | 1 | 1510 |
| Kaic | 156 | Lusuran | 3 | 1 | 1500 |
| | | Cayaban | 51 | 2-3 | |
| | | Mayapa | | | |
| | | Banood | (23) | (7) | Below |
| | | Alola | 4 | | |
| Timilan | 38 | Catloc-Timilan | 13 | 4 | 830 |
| | | Matalin | 5 | | |
| Bay drainage | | Catapayo | | | |
| | | Postema | 9 | 2 | 120 |
| | | Opiso | | | |
| Casas | 22 | | | | |
| | | Banood | 25 | 6 | 1470 |
| | | Panizapan | 25 | 7 | 860 |
| | | Matangilan | | 10 | |
| Ilanlan | 141 | Malan | 17 | 8 | 750 |
| | | Calabub | | 10 | 1190 |
| | | Main river | | 11 | 2670 |
| | | Kanacan | 61 | 9 | 930 |
| | | Joscan | | 15 | 940 |
| | | Casandit | | 13 | 270 |
| Imus | 113 | Tibagan | 43 | 14 | 1630 |
| | | Pasan Buys | 5 | 16 | 840 |
| | | San Cristobal | 10 | 12 | 550 |
| | | Malaguin-ilog | 10 | 18 | 480 |
| | | | 11 | 17 | 510 |
| | | | 5 | others | 300 |
| Lapote | 62 | | | | |
| Bisan | 71 | Malaguin ilog | (18) | (18) | Above |
| | | Zorozo | 51 | 18 | 230 |
| | | Carmona | 10 | 20 | 200 |
| Sta Rosa | 42 | | 32 | 21 | 1080 |
| San Cristobal | 100 | Diamo | 32 | 25 | 200 |
| | | San Cristobal | 33 | 23 | 460 |
| San Juan | 264 | | 222 | 24 | 280 |

189

Total Drainage Area utilized - square kilometers
Total Irrigated Area - Hectares.

55220

Table 4. Final Payments on Friar Lands Estates.

| Estate | Date of Transfer | Previous Owner | Hectares transferred | Price |
|------------------------------|----------------------|------------------------------|----------------------|---------------------|
| <i>Biñan</i> | <i>Oct 19, 1905</i> | <i>Phil. Sugar Ests. Co.</i> | <i>3659</i> | <i>P 601,583.18</i> |
| <i>Calamba</i> | <i>"</i> | <i>"</i> | <i>13673</i> | <i>1,385,443.29</i> |
| <i>Imus</i> | <i>Feb 6, 1905</i> | <i>British Manila Co.</i> | <i>18243</i> | <i>2,072,024.30</i> |
| <i>Naic</i> | <i>Oct 20, 1905</i> | <i>Phil. Sugar Ests. Co.</i> | <i>7624</i> | <i>982,711.53</i> |
| <i>San Francisco-Malabon</i> | <i>Oct 26, 1904</i> | <i>Sociedad Agrícola</i> | <i>11449</i> | <i>1,069,874.82</i> |
| <i>Sta. Cruz de Malabon</i> | <i>Oct. 19, 1905</i> | <i>Phil. Sugar Ests. Co.</i> | <i>9795</i> | <i>1,037,412.43</i> |
| <i>Sta. Rosa</i> | <i>"</i> | <i>"</i> | <i>5470</i> | <i>910,234.72</i> |

Table 5. Cost of Administration of Irrigated Lands.

| Estate | 1907 | | | 1908 | | |
|---------------------------------|------------------------|-------------|-------------------------|------------------------|-------------|-------------------------|
| | Expenses Irrigation | Per hectare | Unrecurrent Expenses | Expenses Irrigation | Per hectare | Unrecurrent Expenses |
| <i>Biñan</i> | <i>P 3,149.24</i> | <i>3.50</i> | | <i>930.59</i> | <i>.90</i> | |
| <i>Calamba</i> | <i>1,620.75</i> | <i>1.56</i> | | <i>744.53</i> | <i>.71</i> | |
| <i>Imus</i> | <i>4,005.15</i> | <i>.40</i> | | <i>2678.06</i> | <i>.27</i> | |
| <i>Lolomboy</i> | <i>49.60</i> | | | | | <i>6536.13</i> |
| <i>Muntinlupa</i> | <i>346.70</i> | | | | | |
| <i>Naic</i> | <i>1268.12</i> | <i>.48</i> | | <i>1037.66</i> | <i>.43</i> | |
| <i>San Francisco</i> | <i>1488.87</i> | <i>.40</i> | <i>6996.18</i> | <i>1475.63</i> | <i>.39</i> | |
| <i>Sta Cruz</i> | <i>2774.53</i> | <i>1.13</i> | <i>6721.64</i> | <i>2621.50</i> | <i>1.11</i> | |
| <i>Sta Rosa</i> | <i>2323.71</i> | <i>2.26</i> | | <i>810.17</i> | <i>.78</i> | |
| <i>Sta Maria Pandi</i> | | | <i>144.14</i> | | | <i>14413.50</i> |
| <i>TOTAL</i> | <i>17026.67</i> | | <i>13861.96</i> | <i>10298.14</i> | | <i>20949.63</i> |
| <i>Total, estates discussed</i> | <i>16630.37</i> | <i>.74</i> | | <i>10298.14</i> | <i>.45</i> | |

Table 6. Estimate of Cost of Replacement of Works

| Estate | Dams | Other Structures | Tunnels | Main Canals | Main Laterals | Total | Hectares irrig | Probable present cost of repl. per. hect. |
|----------------------|------------------|---------------------|-----------------|-----------------|-----------------|------------------|----------------|--|
| <i>Naic</i> | <i>P 150 000</i> | <i>P 15 000</i> | <i>P 80 000</i> | <i>P 28 000</i> | <i>P 15 000</i> | <i>P 288 000</i> | <i>2410</i> | <i>P 118</i> |
| <i>Sta Cruz</i> | <i>1198</i> | | <i>172</i> | <i>40</i> | <i>20</i> | <i>1430</i> | <i>2450</i> | <i>583</i> |
| <i>San Francisco</i> | <i>1033</i> | <i>103</i> | <i>252</i> | <i>50</i> | <i>30</i> | <i>1468</i> | <i>3760</i> | <i>390</i> |
| <i>Imus</i> | <i>1860</i> | <i>186</i> | <i>140</i> | <i>116</i> | <i>45</i> | <i>2347</i> | <i>9880</i> | <i>237</i> |
| <i>Biñan</i> | | | | | | <i>100</i> | <i>1030</i> | |
| <i>Sta Rosa</i> | <i>32</i> | <i>40</i> | <i>32</i> | <i>20</i> | <i>10</i> | <i>134</i> | <i>1980</i> | <i>66</i> |
| <i>Calamba</i> | <i>166</i> | <i>17</i> | <i>96</i> | <i>14</i> | <i>5</i> | <i>298</i> | <i>1040</i> | <i>286</i> |
| <i>Total</i> | <i>4439 000</i> | <i>361 000</i> | <i>772 000</i> | <i>268 000</i> | <i>125 000</i> | <i>6065 000</i> | <i>22550</i> | <i>268</i> |

Table 4. Final Payments on Prior Lands Estates

| Estate | Date of Transfer | Previous Owner | Hectares transferred | Price |
|-----------------------|------------------|----------------------|----------------------|--------------|
| Sta. Rosa | " | " | 2470 | 910,234.75 |
| Sta. Cruz de Malabon | Oct 19, 1902 | Phil. Sugar Est. Co. | 9752 | 1,037,415.43 |
| San Francisco-Malabon | Oct 26, 1904 | Sociedad Agrícola | 11443 | 1,063,874.82 |
| Main | Oct 20, 1902 | Phil. Sugar Est. Co. | 7624 | 985,111.23 |
| Imus | Feb 6, 1902 | British Manila Co. | 18243 | 5,075,024.30 |
| Calamba | " | " | 13673 | 1,382,443.29 |
| Binan | Oct 19, 1902 | Phil. Sugar Est. Co. | 3629 | 601,283.18 |

Table 5. Cost of Administration of Irrigated Lands

| Estate | 1907 | | | 1908 | | |
|--------------------------|---------------------|-------------|----------------------|---------------------|-------------|----------------------|
| | Irrigation Expenses | Per Hectare | Unrecovered Expenses | Irrigation Expenses | Per Hectare | Unrecovered Expenses |
| Sta. Maria Landi | 232371 | 5.26 | 14414 | 81017 | 1.11 | 14413.20 |
| Sta. Rosa | 27443 | 1.13 | 6721.64 | 2621.20 | .39 | |
| San Francisco | 148887 | .40 | 6996.18 | 1472.63 | .43 | |
| Main | 126812 | .48 | | 1037.66 | .27 | |
| Muntinlupa | 34670 | .40 | | 744.23 | .71 | |
| Lolomboy | 4860 | .40 | | 2678.06 | .90 | 6236.13 |
| Imus | 400212 | 1.26 | | 93029 | .78 | |
| Calamba | 1,62072 | 1.26 | | 744.23 | .71 | |
| Binan | 314924 | 3.20 | | 93029 | .90 | |
| TOTAL | 1702667 | 13861.96 | 10288.14 | 10288.14 | .42 | 50249.63 |
| Total, estates discussed | 16630.37 | .74 | | 10288.14 | .42 | |

Table 6. Estimate of Cost of Replacement of Works

| Estate | Dams | Other Structures | Tunnels | Main Canals | Main Laterals | Total | Hectares irrigated | Probable price of repl. per hect. |
|---------------|---------|------------------|---------|-------------|---------------|---------|--------------------|-----------------------------------|
| Calamba | 166 | 17 | 26 | 14 | 2 | 288 | 1040 | 286 |
| Sta. Rosa | 32 | 40 | 32 | 20 | 10 | 134 | 1980 | 60 |
| Binan | | | | | | 100 | 1030 | |
| Imus | 1860 | 186 | 140 | 116 | 42 | 2347 | 9880 | 337 |
| San Francisco | 1033 | 103 | 222 | 20 | 30 | 1468 | 3760 | 390 |
| Sta. Cruz | 1198 | | 172 | 40 | 20 | 1430 | 2420 | 283 |
| Main | 120000 | 12000 | 80000 | 28000 | 12000 | 288000 | 2410 | 118 |
| TOTAL | 4439006 | 361000 | 772000 | 268000 | 122000 | 6062000 | 25220 | 268 |

strict, and knows that the dry season supply is insufficient. Tres Cruces dam however acts somewhat as a storage dam. Unit 5 is a storage and concentration system, which should be sufficiently supplied in both seasons.

The Cañas River is capable of supplying water from a drainage area of 92 sq. km. A good deal of its water is taken up by the Bancod system of dams, and goes directly to supply unit 7; but some descends down the main river to the Molino Sta Cruz dam, which supplies unit 6 in Sta Cruz, and some mostly seepage and run-off arrives at the Policena dam, which aids in irrigating unit 10.

Now, turning to the Ualan River and Arroyo Calubcub, it is seen that the flow off from 17 sq. km. must first irrigate the 720 ht. of unit 8. In the rainy season enough water could be passed by the upper diversion to irrigate 150 ht. of unit 10 at the Antigo dam. Of course, ordinarily there is some flow off, but the writer is assuming that there would not be with the theoretical duty supply. In the dry season, if the upper dam was diverting all its water, the lower one would be dry, which the writer knows is practically the case when the gates on the upper dam are open. Therefore only about one fifth of unit 8 could be irrigated in the dry season.

All the water of the main Cañas, from a drainage area of about 50 sq. km., passes to the dam Molino Sta Cruz. In the dry season this would irrigate about 500 ht., or one third of unit 6 if no water passed the dam. In the rainy season the whole area could be irrigated, and sufficient water passed down to Policena to irrigate all of unit 10.

On account of insufficient supply, the Bancod tunnel was built, which adds a tributary area of 23 sq. km. to unit 7. There

are also about 40 sq. km. tributary to that unit from the Cañas. This supply should be nearly sufficient to irrigate the unit in the dry season. If only one half were irrigated, enough could be passed to supply 200 ht. of unit 10, at the Antigo dam, or about one fifth of the area of the latter unit. In the rainy season all of units 7 and 10 can be reached. This is one of the most complicated combination of units met with, and the writer has endeavored to show how any desired amount of each unit could be irrigated in seasons of sufficient water by a very simple system of weir gates on the crests of the dams. After definite information as to the flow of the rivers is obtained, rotation agreements could be made with the landowners on the various units, and the systems be regulated very closely. This is now partially effected by opening and closing the headgates of the canals.

We have already discussed the Ualan River, which is a tributary of the Ilanilan; but the main branch of the latter with its upper tributaries serves as a supply for another very complicated combination of units. The total drainage area considered is 61 sq. km. on which depend 5170 ht. of land. All of this area can hardly be irrigated in the rainy season, altho a very complete system of drainage re-diversion is employed in the lower portion of the units. In the dry season very little land can be reached, and this will probably be entirely in unit 11, which has the uppermost dam, San Agustin; the lower unit 9, in San Francisco, will be dry. The writer has observed the small amount of water on this district in the dry season; and can see no remedy for this state of affairs, since all the surrounding rivers are utilized. About one fourth

of unit 11 will be irrigated in the dry season.

The dam Trapiche irrigates 1650 ht. of unit 14 from the River Tibagan, which has an area of 49 sq. km. This should be sufficient for complete rainy season irrigation and to supply one third of the land in the dry season.

We must consider the Malaquin-ilog, which brings a tributary area of 13 sq. km. to the Embarcadero dam. This will be a little more than sufficient to irrigate unit 18 during the rainy season; but only about one third of it can be irrigated in the dry season. The same unit picks up water from the San Cristobal River, which however will supply but little. The excess will go to units 15 and 16 (1060 ht.) and theoretically most of their areas should be irrigated in the rainy season. This is however not always the case at present, due to uneconomic use of water. None of the land can be reached in the dry season.

Unit 17 depends on the storage dam, Molino, which receives drainage from units 15, 16 and 18. The primary area will only supply 500 ht. in the rainy season; but owing to the reservoir there is no doubt that nearly all the area can then be irrigated. The writer has seen the reservoir in the dry season, and even then it contains considerable water. This combination of units presents a very trying problem. By reference to Table 3, page 137, it can be seen that the Zapote River has a large area, and it is a fact that the Ligas dam, irrigating a small parcel in lower Imus, is even during the dry season generally overflowing. This river might be tapped further up and made to supply parts of unit 17 in the dry season. However, the cost of such a diversion would be great, and it might be impractical for other reasons.

The remainder of the area in Laguna is not at all complicated, and the results of similar operations to the above give the following figures:

| UNIT | IRRIG. DRY SEASON | IRRIG. RAINY SEASON |
|------|-------------------|---------------------|
| 19 | 1/2 | All |
| 20 | 1/5 | All |
| 21 | 1/3 | All |
| 22 | 2/5 | All |
| 23 | 3/4 | All |
| 24 | All | All |

The writer has not attempted to discuss the locations where small cross diversions might be made, or to describe the equalization of a smaller supply than one sec. lr. per hectare, as that would in his opinion only necessitate a more efficient set of agreements for rotation within the units themselves.

It will be seen that under the present usage the available supply is less than sufficient for the complete dry season irrigation of one half the area under ditch, while almost all of it can be reached during the rainy season. This is as the writer would expect from what he has been able to observe.

Three things will be necessary for the adjustment of these supplies economically: (1) a complete survey of the lands in question to find exactly from where each parcel receives its water; (2) a study of the various rivers to determine their behavior in various seasons; and (3) the most important, the education of the landowners to an idea of the economic use of water and of the principle of give and take.

ACKNOWLEDGMENTS AND TRANSMITTAL. The question will undoubtedly come up as to how authoritatively the writer is entitled to

speak on the subject of this paper. He refers whom it may concern to a communication from the Chief Irrigation Engineer, Bureau of Public Works, permitting him the use of the official records in preparing the paper under the condition that a copy should be left in the office for reference. This would seem to sufficiently guarantee the writers authority and also the care of the preparation.

It must be remembered that the difficulties attending the gathering of data were great, that altho close to Manila the condition of the roads and trails are such as to make travel very inconvenient, many of the works being reached only after cutting for distances thru brush or forest. At the time of writing the majority of the irrigation engineers and employees knew so little about these great works as to acknowledge that they knew nothing whatever from an engineering standpoint. No engineering maps of the irrigation of the Cavite Friar lands existed at the time of writing, those presented here being sketches on skeletons of Bureau of Land's plats, accurate as an area but not so as regards irrigation data. The Laguna works have perhaps been treated a little more fully than those in Cavite, as they are better known to the writer besides being the better preserved.

In the light of the above, it will be seen why the writer lays no claim to theoretical accuracy. His object in presenting this as an engineering paper is not that it should be considered in the nature of laboratory data, but that it should outline the broad conditions and development of a great irrigation work. He does claim however that he has made apologies for his data wherever he can not positively depend on them, that his data were the best available at the time, and that the data would have been considered

sufficiently accurate for any purpose at the date of writing.

The writer has already given an outline of most of the work personally done by him on the Friar Lands; but besides that mentioned he has made a great many trips to various other works. He would however have been handicapped without the assistance rendered by Mr. McCord, Superintendent of Irrigation; Mr. McGregor of the Irrigation Division who lent him valuable photographs; and Messrs. Kirkpatrick and Wrentmore, past and present heads of the Irrigation Division, who secured for him the permission of the Director of Public Works to use official records in the preparation of this paper.

The writer is disappointed that circumstances impelled him to discontinue his connection with the Bureau of Public Works at a time when he could have entered upon a thorough investigation of the works of Javite and have observed an able irrigation survey of the same district. Under the circumstances it is needless to submit engineering data which may soon be replaced by more accurate ones, beyond a point necessary to give the outsider some idea of the quantities, distances, and relations considered.

He presents the paper as of possible use in gaining a correct idea of the larger phases of water rights and intelligent control, and as siftings from a very complicated mass of information and conjecture; and presents it to his past employer, the Bureau of Public Works, with the hope that it may present a few unconsidered points on the question of Friar Lands irrigation which may be of value. He believes, however his views may be considered, that it will be conceded that the paper was written as a result of the most careful study, and that the writer was sufficiently experienced in the work to form intelligent opinions on the subject.

APPENDIX.

CONVERSION TABLE -- METRIC TO ENGLISH

LENGTHS

| | | |
|------------------------------|---|----------------|
| 1 millimeter (mm.) | = | 0.03937 inches |
| 1 centimeter (cm.) | = | 0.3937 inches |
| 1 meter (m.) | = | 3.2808 feet |
| 1 kilometer (km.) | = | 0.62137 miles |

AREAS

| | | |
|---|---|---------------------|
| 1 square centimeter (sq. cm.) | = | 0.155 square inches |
| 1 square meter (sq. m.) | = | 10.764 square feet |
| 1 hectare (ht.) = 100 sq. m. | = | 2.471 acres |
| 1 square kilometer (sq.km.) | = | 0.3861 square miles |

VOLUMES

| | | |
|---------------------------------------|---|---------------------|
| 1 cubic centimeter (cu.cm.) | = | 0.0283 cubic inches |
| 1 cubic meter (cu. m.) | = | 35.32 cubic feet |
| | = | 1.308 cubic yards |

MASSES

| | | |
|----------------------------|---|--------------------|
| 1 kilogram (kg.) | = | 2.2046 pounds adv. |
|----------------------------|---|--------------------|

CAPACITIES

| | | |
|--------------------------------------|---|-------------------|
| 1 liter (lr.) = 1000 cu. cm. | = | 0.0353 cubic feet |
| | = | 0.2642 gallons |
| 1 cavan, Spanish, | = | 2.13 bushels |

FLOW OF WATER

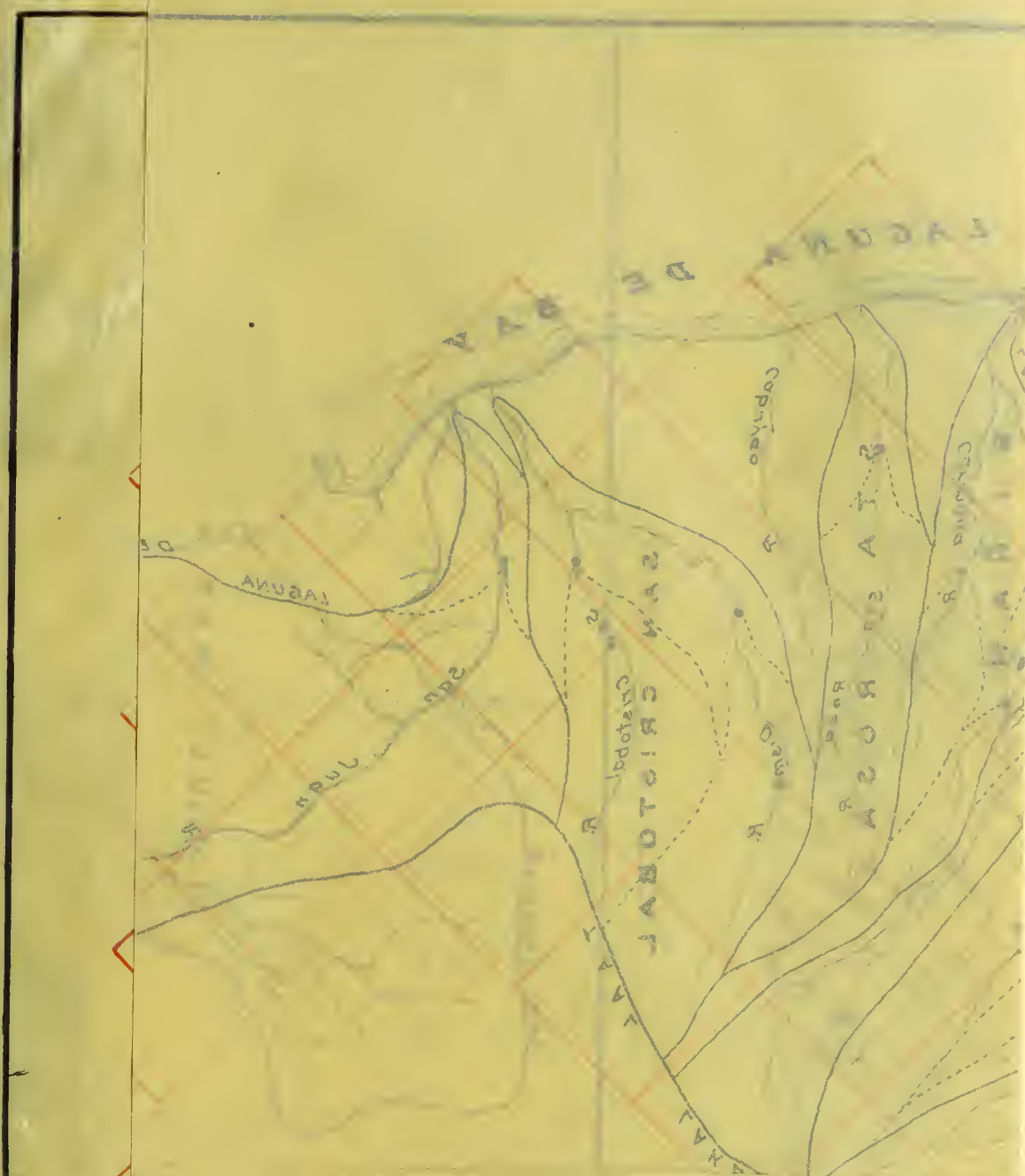
| | | |
|--|---|------------------------------|
| 1 liter per second (sec.lr.) | = | 0.0353 cubic feet per second |
| | = | 1.5852 gallons per minute |

DUTY OF WATER, ETC.

| | | |
|--|---|--|
| 1 liter per second per hectare (sec. lr. ht.) | = | 0.0143 cubic feet per second per acre |
| 1 liter per second per square kilometer (sec.lr.sq.km.) | = | 0.0916 cubic feet per second per square M |

CURRENCY

| | | |
|---------------------------------|---|-------------------|
| 1 peso (₱) = 100 centavos (ct.) | = | \$0.50 (American) |
|---------------------------------|---|-------------------|





MAP OF
THE TRIBUTARY DRAINAGE
AREAS OF CAVITE
& LAGUNA

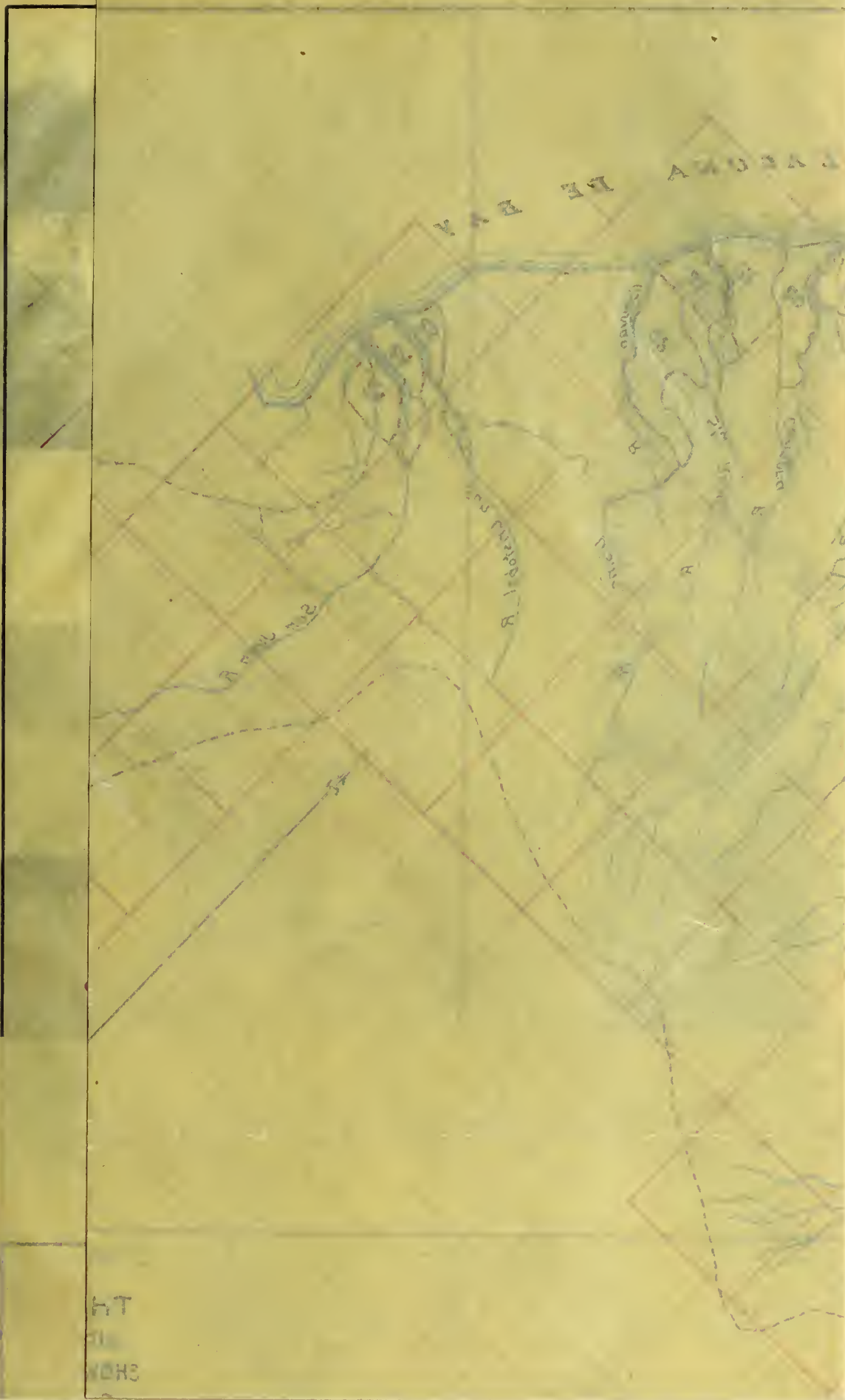
Compiled by S.G. Cutler from
various data

Scale 1:200000

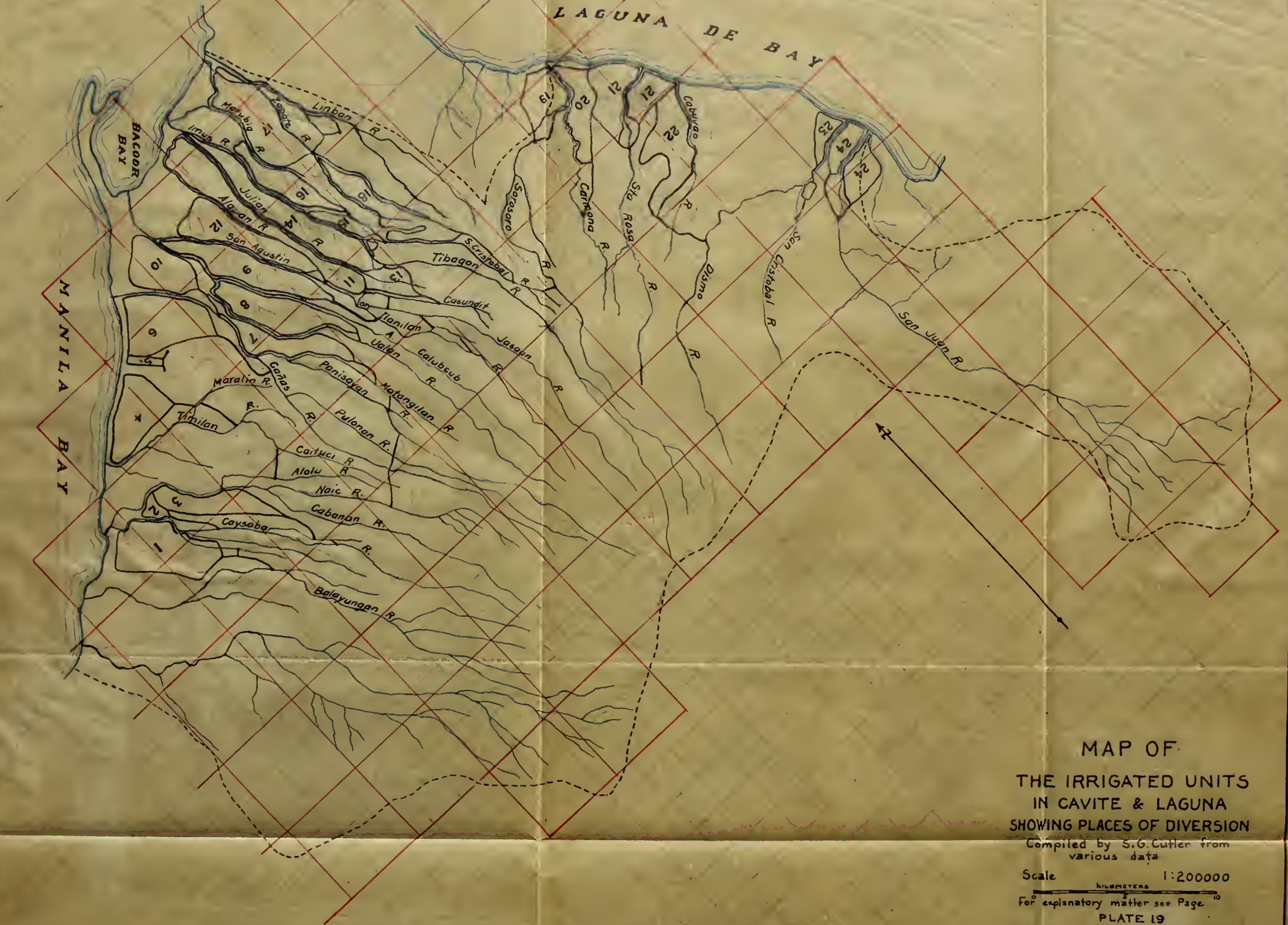
For explanatory matter see Page 10

PLATE 18

To accompany treatise by S.G. Cutler.



HT
TH
WCHS



MAP OF
THE IRRIGATED UNITS
IN CAVITE & LAGUNA
SHOWING PLACES OF DIVERSION

Compiled by S.G. Cutler from
various data.

Scale 1:200000

KILOMETERS
For explanatory matter see Page 10

PLATE 19

To accompany treatise by S.G. Cutler.



1. ARAPOO RIVER IN FLOOD, MALABON, CAVITE.



2. FLOOD ABOVE PERS CRUCES DAM
Sta Cruz, Cavite



3. MAROPIO DAM AND GORGE
San Francisco de Malabon.



4. POLICENA DAM SHOWING WASH-
OUT AT TOP.

San Francisco de Melabon.



5. ANTIGO DAM, SHOWING FLASH
BOARD ON CREST.



6. CORNER OF WALL, TRES CRUCES
SHOWING CONDITION OF MASONRY



7. DOWNSTREAM FACE OF TRES
CRUCES DAM.



8. GATE INSTALLMENT AT TRES CRUCES 9. SMALL CANAL AND AQUEDUCT

Sta Cruz, Cavite



near Tolicena dam.



4813

10. DITCH AND A DRAINAGE
Near Pao dan, Sta Cruz.



11. RICE FIELD
San Francisco de Macabon



12

WICK-QUARRY
SAND SALT-TRAIL DAM -
Imus, Cavite.



13

PRESILLA CASUNDIT
WITH BAMBOO CREST
Imus, Cavite.

14

THE FIRST AQUEDUCT-BANCOO
PALAUIT SYSTEM



15

FIRST AQUEDUCT-BANCOO

PALAUIT SYSTEM

Showing eastern end of tunnel.





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